

NASA Contractor Report 182077

Aerodynamic Preliminary Analysis System II Part II - User's Manual

G. Sova and P. Divan

ROCKWELL INTERNATIONAL CORPORATION
Los Angeles, California, 90009

CONTRACT NAS1-18015

APRIL 1991



National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665-5225

(NASA-CR-182077) AERODYNAMIC PRELIMINARY
ANALYSIS SYSTEM 2. PART 2: USER'S MANUAL
(Rockwell International Corp.) 339 p

N91-23081

CSCL 01A

63/02

Unclass
0012355

AERODYNAMIC PRELIMINARY ANALYSIS SYSTEM II

PART II USER'S MANUAL

By G. Sova, P. Divan, L. Spacht

North American Aircraft Operations, Rockwell International

SUMMARY

An aerodynamic analysis system based on potential theory at subsonic/supersonic speeds and impact type finite element solutions at hypersonic conditions is described. Three-dimensional configurations having multiple non-planar surfaces of arbitrary planform and bodies of non-circular contour may be analyzed. Static, rotary, and control longitudinal and lateral-directional characteristics may be generated.

The analysis has been implemented on a time sharing system in conjunction with an input tablet digitizer and an interactive graphics input/output display and editing terminal to maximize its responsiveness to the preliminary analysis problem. Computation times on an IBM 3081 are typically less than one minute of CPU/Mach number at subsonic, supersonic or hypersonic speeds. Computation times on PRIME 850 or a VAX 11/785 are about fifteen times longer than on the IBM. The program provides an efficient analysis for systematically performing various aerodynamic configuration tradeoff and evaluation studies.

TABLE OF CONTENTS

Section		Page
1	INTRODUCTION	1
2	SYSTEM OVERVIEW	2
3	GEOMETRY	5
	Components	7
	Geometrics	7
	Analysis	12
	Numbering	12
	Configurations	13
	Input	15
	Simple	15
	Arbitrary	15
	Processing	19
	Display	19
	Editing	19
	Component Management	20
	Sample Sessions	27
	Simple Configuration	27
	Arbitrary Configuration	50
4	ANALYSIS	80
	Foreground	80
	Background Setup	80
	Sample Sessions	82
	Foreground	82
	Background Setup	90

Section		Page
5	ANALYSIS OUTPUT	105
	Print	105
	Display	115
	Sample Sessions	118
6	COMMAND/SUBCOMMAND DICTIONARY	131
APPENDIX A	CARD COMMAND INPUT DESCRIPTION	277
APPENDIX B	POINT SPACING, INTERPOLATION AND GEOMETRY TRANSFORMATIONS	287
APPENDIX C	OUTPUT VARIABLE DESCRIPTIONS	278
APPENDIX D	SYSTEM SUBROUTINE DESCRIPTIONS	291
APPENDIX E	ALTERNATE PROGRAM USAGE	312
REFERENCES	326

LIST OF ILLUSTRATIONS

Figure No.	Title	Page
2-1	APAS II Organization	3
2-2	System Activity and Command/Procedure Relationships . . .	4
3-1	Cross-section Segmentation	9
3-2	Surface Components	10
3-3	Airfoil Segmentation	10
3-4	Multiple Interference Shells Use	11
3-5	Typical Slender Body Cross-sections	11
3-6	Two Configurations from a Single Geometry File	14
3-7	TERMINAL Airfoil Sections Command	14
3-8	Digitizing Points for Sections Having Converging Segments	16
3-9	Preparing Surfaces for Digitizing	16
3-10	Airfoil Reference Line	18
3-11	Three-view Display	22
3-12	Orthographic Display	23
3-13	Windowing into a Potential Trouble Area	24
3-14	Perspective Viewing	25
3-15	Hidden Panel Display	26
3-16	TERMINAL Input of a Simple Fuselage	30
3-17	Simple Fuselage Display	31
3-18	Fuselage Modification by Section Translation	31
3-19	Inserting Sections and Modifying Fuselage Nose	32
3-20	Viewing and Saving Modified Simple Fuselage	33
3-21	TERMINAL Input of Simple Wing	34
3-22	Wing Viewing Using Auxiliary Component	35
3-23	Translating the Wing	36
3-24	Increasing the Viewing Space and Modifying the Wing Leading Edge	37
3-25	Final View of Simple Wing Modifications	38
3-26	Three-view of Simple Wing and Fuselage	38
3-27	Modifying a Fuselage Section Using the EDIT/XH Cross Hair Subcommand	39
3-28	Modified Cross-section from Figure 3-27	40
3-29	Final View of Modified Cross-section	41
3-30	Modifying a Cross-section Using the Z and Y Subcommands of EDIT	42
3-31	Modified Section from Figure 3-30 and Z and Y Changes to Sections 9, 8, 7, and 6	42
3-32	Rounding Off the Bottom of Section 6	43
3-33	List of section 6 Modifications and Saving the Fuselage .	43
3-34	Front View of the Simple Fuselage	44
3-35	Three View of Simple Wing and Fuselage Showing Improved Wing-body Interface	44
3-36	Using the Maximum Half Thickness of Wing Section 1 to Change ZO from -3.048 to -2.362	45
3-37	Three-view Showing Wing in its Final Position on the Fuselage	46
3-38	Vertical Tail TERMINAL Input	47

3-39	Viewing the Vertical and Widening the Viewing Space	48
3-40	Vertical Tail Translation	49
3-41	Configuration Three-view	49
3-42	Space Shuttle Orbiter Three-view	51
3-43	Space Shuttle Orbiter Components	52
3-44	Fuselage Partitioning for Digitizing	52
3-45	Examples of Digitizing Sections on Various Body Components	53
3-46	Previewing Wing Surface, Adding Guide Lines and Transfer Lines for Digitizing	54
3-47	Previewing Vertical Tail, Adding Guide Lines and Transfer Lines for Digitizing	54
3-48	Forward Fuselage General Digitizing Input	55
3-49	Digitizing Forward Fuselage Section 1	57
3-50	Digitizing Forward Fuselage Section 2	57
3-51	Digitizing Forward Fuselage Section 3	58
3-52	Digitizing Forward Fuselage Section 5	58
3-53	Digitizing Forward Fuselage Section 6	59
3-54	Digitizing Forward Fuselage Section 7 and Ending Component Digitizing	59
3-55	Body Contour Processing	60
3-56	Three-view of Digitized Forward Fuselage	60
3-57	Mid Fuselage General Digitizing Input	61
3-58	Aft Fuselage General Digitizing Input	61
3-59	Pod General Digitizing Input	62
3-60	Digitized Pod Contour	62
3-61	Fuselage Three-view	63
3-62	General Input for Wing Digitizing	64
3-63	Digitizing Wing Section 1	65
3-64	Digitizing Wing Section 2	65
3-65	Digitizing Tip and Ending the Wing Input	66
3-66	Processing Wing Section 1	66
3-67	Processing Wing Section 2	67
3-68	Processing Wing Tip	67
3-69	Complete Configuration Three-view	68
3-70	Selecting Body Components for Generating the Slender Body	69
3-71	SLENDER Component Linking	70
3-72	Entries Required to Generate a Slender Body from Several Fuselage Components	70
3-73	Orthographic Projection of Slender Body	70
3-74	Slender Body Editing Using Forward Fuselage	71
3-75	Viewing Slender Body with the Forward Fuselage (dashed line) as an Underlay	71
3-76	Adding Sections to the Nose of the Slender Body Using the Forward Fuselage as Reference	72
3-77	Scaling New Sections to Match the Forward Fuselage Contours	72
3-78	Plan View Corrections to Match Forward Fuselage	73
3-79	Three-view Display of Slender Body Modifications	73
3-80	Thinning Slender Body Sections	74
3-81	Inserting Adjusting Sections in Aft Fuselage	75
3-82	Rounding Off the Slender Body Crew Station	75
3-83	INTERFERENCE Command General Input	76

3-84	Interference Shell Construction	76
3-85	Interference Shell Paneling	78
3-86	Wing-flap Paneling	78
3-87	Vertical Tail-flap Paneling	79
4-1	Assembling Local File Configuration and Initiating the VISCIOUS Command	83
4-2	Perimeter Distribution and Wetted Area	84
4-3	Area Distribution and Volume	84
4-4	VISCIOUS Calculation Input Parameters	85
4-5	VISCIOUS Detailed Print at M=0.6	86
4-6	VISCIOUS Detailed Print at M=1.2	86
4-7	VISCIOUS Summary Print	87
4-8	Exiting VISCIOUS and Entering WAVEDRAG Command	88
4-9	WAVEDRAG Output at M=1.2	88
4-10	WAVEDRAG Output at M=1.6	89
4-11	Assembling a Configuration and Initiating the SET Command and Subcommand	91
4-12	Creating a Run Schedule Using the ADD Subcommand	92
4-13	Modifying an Existing Run and Listing the Run Schedule and Configuration	93
4-14	Ending SET and Initiating Analysis Model Verification	94
4-15	Subsonic-supersonic Analysis Paneling	95
4-16	Wing Camber Distribution	95
4-17	Wing Thickness Distribution	96
4-18	Surface Twist Distribution	96
4-19	Defining Viscous Drag Parameters	97
4-20	Hypersonic Configuration	97
4-21	Hypersonic Analysis Methods for the Fuselage and Pod	98
4-22	Hypersonic Methods for Wing, Vertical Tail and Body Flap	102
4-23	Orthographic Projection of the Hypersonic Geometry Model	103
4-24	Top View of the Hypersonic Geometry Model	104
5-1	Slender Body Solution	107
5-2	Viscous Solution Wetted Area and Volume Summary	107
5-3	Lifting Surface Solution Header Page	108
5-4	Subsonic-supersonic Panel Solution Forces and Moments	108
5-5	Volume Wave Drag Solution	109
5-6	Lifting Wave Drag Solution	110
5-7	Viscous Drag Solution	110
5-8	Subsonic-supersonic Analysis Summary	111
5-9	Hypersonic Analysis Configuration	111
5-10	Hypersonic Analysis Panel Summary	112
5-11	Hypersonic Analysis Component Summary	112
5-12	Hypersonic Analysis Total Configuration Summary	113
5-13	PLOT Form 1 Display	116
5-14	PLOT Form 2 Display	116
5-15	PLOT Form 3 Display	117
5-16	PLOT Command Entry and Listing of Runs Currently Available in the Output File	118
5-17	Listing of Runs in Current Output File and Entering Subcommand to Display C_L Versus α	118
5-18	Pre-plot Page for Lift Display	118

5-19	Display of C_L Versus α	119
5-20	Utilizing the SET Subcommand to Specify New Plotlists and Plotting the Current Runlist	120
5-21	Preplot Page for Drag Polar Display	120
5-22	Display of Lift Versus Drag	121
5-23	C_L Versus C_M Display Request	121
5-24	C_L Versus C_M Display	122
5-25	Run 3 C_L Versus C_M Display Request	122
5-26	Run 3 C_L Versus C_M Display	122
5-27	Input for Displaying Mach Number Variation of Longitudinal Aerodynamic Derivatives	123
5-28	Longitudinal Display Pre-plot Page	124
5-29	Mach Number Display of Longitudinal Characteristics	125
5-30	Input for Displaying Lift and Lift Curve Slope	125
5-31	Lift Characteristics Displayed as a Function of Mach Number and Angle of Attack	126
5-32	Longitudinal Stability and Lift Versus Pitching Moment Display Request	126
5-33	Longitudinal Stability as a Function of Mach Number and Lift Versus Pitching Moment	127
5-34	Drag at $\alpha=0$ and C_L Versus C_D Display Request	127
5-35	Drag Characteristics as a Function of Mach Number and Lift	128
5-36	Input for Displaying Lateral-directional Characteristics as a Function of Mach Number	128
5-37	Lateral-directional Characteristics Displayed as a Function of Mach Number	129
6-1	Command/Subcommand by System Activity	131
6-2	Modified Paneling Process with Prompts/Responses	169
6-3	Surface Region, Paneling and Flap Specification	170
6-4	Verification of Surface Region, Paneling and Flap Specification	171
6-5	B-1B Inlet Geometry	216
6-6	Verifying Wing and Inlet Geometry Alignment	217
6-7	Paneled View of Inlet with Jet-box Component	218
6-8	Ring-Wing Construction Using TERMINAL Command.	219
6-9	EDIT/VIEW of Ring-Wing Component with Section Deletion	221
6-10	EDIT/VIEW of Ring-Wing Component with Reduced Sections	222
6-11	Ring-Wing Component Modification Using EDIT/B	223
6-12	Ring-Wing Component Modification Using EDIT/X,Y,Z	223

LIST OF TABLES

No.		Page
1	Component Symmetry Parameters	8
2	Component Numbering	13
3	Simple Body Input Data	28
4	Simple Surface Input Data	28
5	Aerodynamic Parameter Storage	115
6	System Activity and Commands Versus Section	132
7	Command Index	133
8	Analysis Plot Variables	200
9	Analysis Initial Conditions	226
10	EDIT sub-command PR variable name definition	241
11	Equivalent Sand Grain Roughness	262
12	Airfoil Thickness Correction Factors	262

LIST OF ABBREVIATIONS AND SYMBOLS

A	Angle of attack
APAS	Aerodynamic Preliminary Analysis System
AR	Aspect ratio
B	Angle of side slip
b	Span. See figure 3-2
C	Chord. See figure 3-10
\bar{c} , CBAR	Mean aerodynamic chord
CK	Airfoil form factor coefficient for linear thickness ratio term
<CR>	Terminal carriage return
C_R	Root chord. See figure 3-2
CRL	Component reference line
C_t	Tip chord. See figure 3-2
Dl,...	Flap #? deflection,...
FF	Component form factor
FRL	Fuselage reference line
HABP	Hypersonic Arbitrary Body Program
M,Mach	Mach number
OK .	APAS ready mode
PERIM	Perimeter
[SP]	Terminal space bar
S	True surface area
S_{wet}	Wetted area
T/CR	Root chord maximum thickness ratio

T/CT	Tip chord maximum thickness ratio
X(),A(),W/H	Station, cross-sectional area, width/height ratio. (Table 3)
X-Area	Cross-sectional area
X,Y,Z	Axial, lateral, vertical cartesian body axis coordinates
XO,YO,ZO	Section origin
XRO,YRO,ZRO	Component origin
X-STAT	X station
XTRANS/LENG	Transition distance as a fraction of component length or chord
λ	Surface taper ratio
$\Lambda_{L.E.}$	Leading edge sweep-degrees
Γ	Dihedral angle-degrees
[]	Letter in brackets is the indicated screen input for a cross-hairs command
→→→	Keyboard input
α	Angle of attack-degrees
β	Angle of side slip-degrees
P	Roll rate - rad/sec
Q	Pitch rate - rad/sec
R	Yaw rate - rad/sec

SECTION 1

INTRODUCTION

A subsonic-supersonic-hypersonic aerodynamic analysis code was developed by integrating an inhouse version (called Unified Distributed Panel or UDP) of the Woodward¹ (subsonic-supersonic) panel program and an inhouse enhanced version of the Hypersonic Arbitrary Body Program² (HABP). This analysis system is called the Aerodynamic Preliminary Analysis System^{3,4} (APAS), which has contained within it an interactive portion which allows the user to setup and preview geometry and analysis models before commitment to analysis. The UDP module was extended to include non-linear vortex forces using a generalization of the Polhamus analogy. The resulting interactive system develops appropriate aerodynamics models from a single input geometry data base and has a run/output format similar to a wind tunnel test program. A description of the pertinent theory is presented in Part I.

The user's manual has been organized to sequentially cover the principal system activities of a typical application. That is, geometric input/editing, aerodynamic evaluation, and post analysis review/display. Sample sessions are provided for each to illustrate the specific tasks involved. This text is followed by a comprehensive command/subcommand dictionary that is used to operate the system.

It is recommended that new users exercise the sample cases or their equivalents. Speed should not be a consideration initially. Obtaining desired simulations often requires repeating steps several times. Like any tool, practice is required. Since the system provides several alternative ways to process a job, the user is encouraged to experiment in order to determine which paths best suit his needs.

A well trained analyst can evaluate a configuration in one working day. Since most of the aerodynamic analysis is performed in background, three sessions are typically required. The first is associated with geometry input and checkout, the second with run schedule setup, and the third with display of results and preparation of additional runs if necessary.

SECTION 2

SYSTEM OVERVIEW

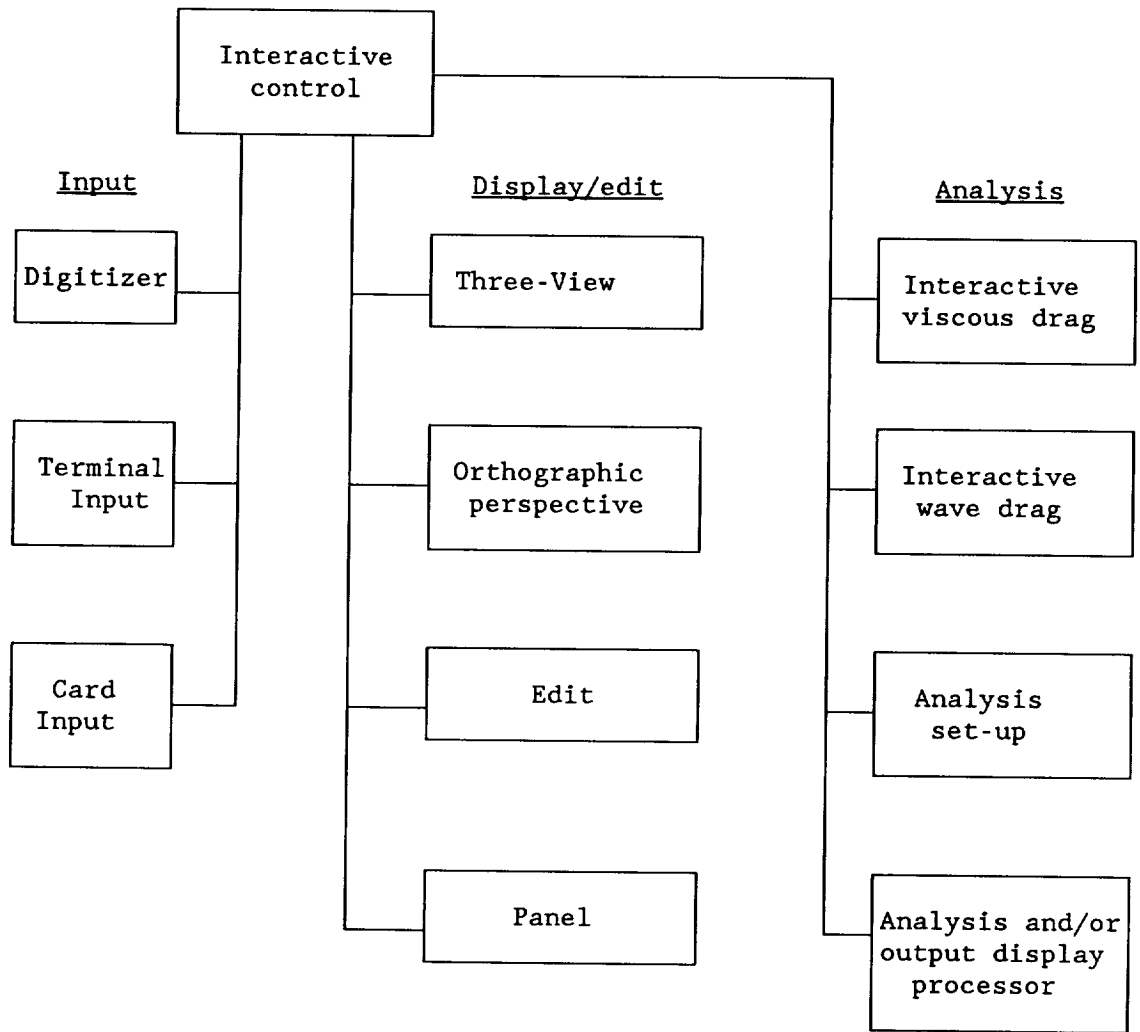
APAS II is the fourth evolution of a system which began with an interrogative response approach and evolved into a command oriented system in order to reduce user response demand. Although not as easy to learn as the former its productivity is far superior. In addition, it has the ability to operate over a wide range of sophistication by accessing fewer or more options on a particular problem.

The system structure is presented on figure 2-1. The program flow is from left to right. In general, the procedure is a fairly straight forward pattern of input, storage, preview, analysis, and review. System activity and command/subcommand or procedure relationships are summarized on figure 2-2. Input manipulation, and verification of geometry (squares one through four) are described in section 3. The interactive analysis and run set up for background evaluation (square five) are detailed in section 4. Display of aerodynamic results (square six) are described in section 5. Utility commands (square seven) are provided to maintain geometry file identification and set or modify various system defaults. Alternative program link-ups (square eight) assist the user in creating data files for other programs or users. The use of some of these procedures are described in Appendix E. All key words in this square are available only upon EXITing from APAS. Entering any of these keyword names invokes a procedure which performs the intended function - which in this case is to create interface data for other programs. APASOUT converts an APAS binary geometry file to card image, which among other uses can be helpful in writing interfaces with other systems. APASIN converts an APASOUT card image data set to a binary geometry file which can be used directly in APAS. These latter two codes⁵ are useful for shipping data between users at different locations. PATRANG,⁶ MBYU,⁷ and COLOR⁷ are helpful in processing output data (shaded model views, isobars, isotherms, etc). PATRANG is available by lease only. MBYU can be purchased for about \$1000. COLOR is similar in function to PATRANG and MBYU. However, it is a Rockwell proprietary code and is not available for general distribution. A detailed system command/subcommand dictionary is presented in section 6 and can be referred to directly by the experienced analyst.

APAS II is coded in FORTRAN-77 and has been implemented on IBM 3081, PRIME and VAX machines. The system contains three separate programs: the interactive input/output program, the subsonic-supersonic analysis program (UDP), and the hypersonic analysis program (HABP).

The interactive program uses Tektronix PLOT10 software for graphics display and a 4014 model Tektronix graphics terminal with a large tablet. Enhanced graphics is recommended over smaller less equipped scopes and any Tektronix graphics terminal starting with models 4014 and up may be used productively. The data transmission rate to the interactive terminal should be at least 1200 BAUD (120 characters per second) and preferably at 9600 BAUD for efficient use of the man-in-the-loop with machine process.

FOREGROUND



BACKGROUND

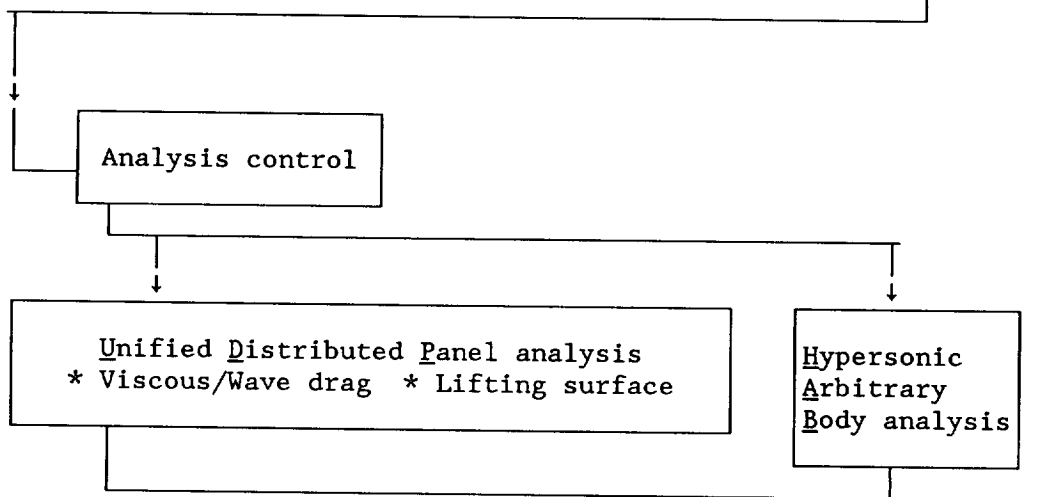


Figure 2-1. APAS II Organization.

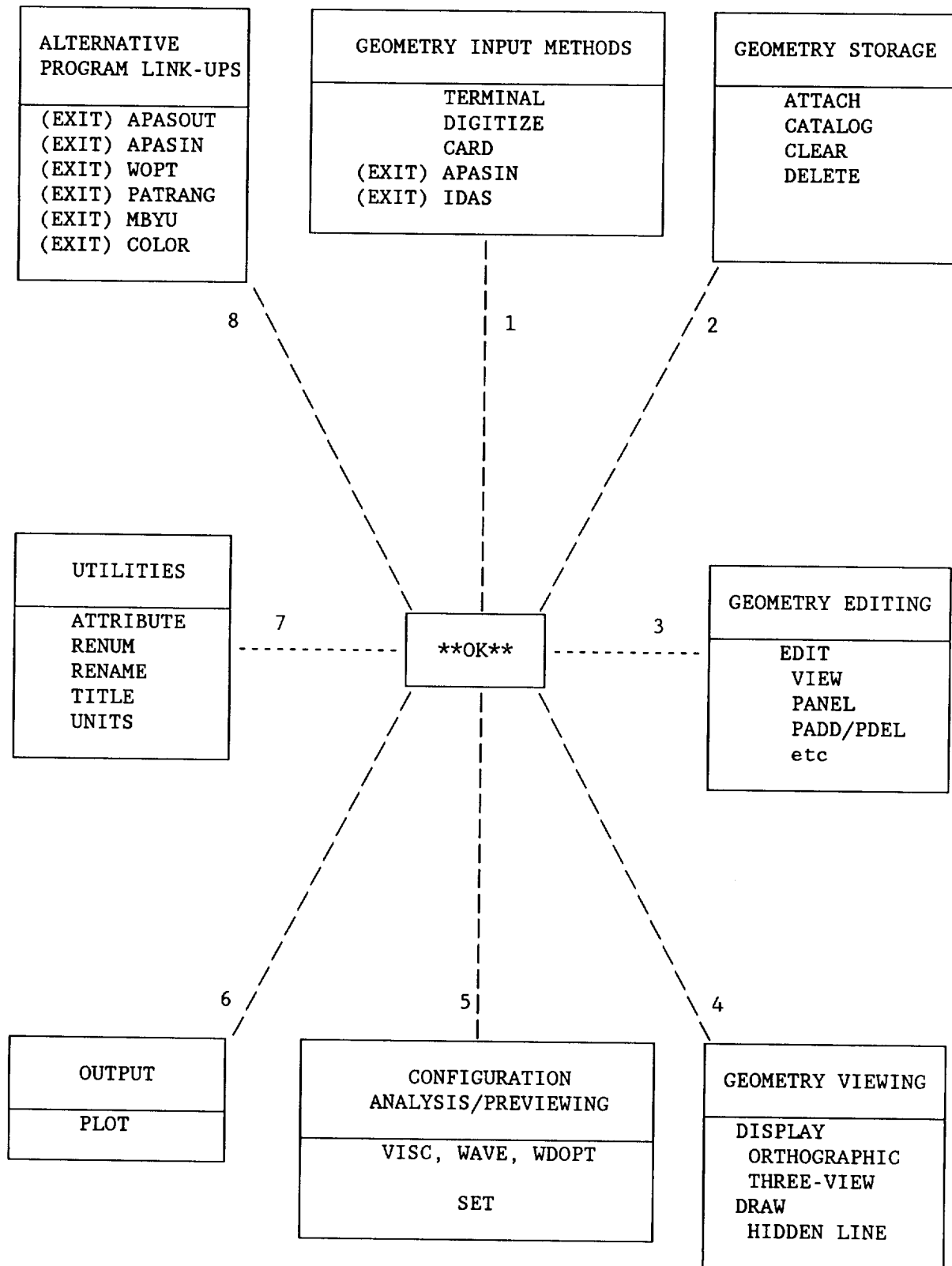


Figure 2-2. System Activity and Command/Procedure Relationships.

SECTION 3

GEOMETRY

Geometric simulation and input procedures are described. Supporting interactive display and editing activities are defined. Two work sessions of increasing complexity are provided to illustrate these system tasks for the beginning user.

A multiple body/surface component description was adopted for air vehicle definition. This approach facilitates arrangement studies, regional modification or replacement and the evaluation of component contributions and interactions. In addition, aerodynamic analysis sensitivities may be established by variation of component force algorithms where pertinent.

Geometric input is by one of five ways; generate simple geometric shapes via keyboard input while using the TERMINAL command, digitize geometric shapes from a three-view drawing using a graphics tablet, pen, and the DIGIT command, read in (via the CARD command) a data file previously constructed according to the format of appendix A, using the APASIN procedure - create a binary geometry file from a card image data set of an existing geometry file (which is provided by the APASOUT procedure), and taking data from a data base manager (such as GEOMOD⁸, or Rockwell's IDAS⁹, etc) for which an interface has been written with APAS. Storage format is independent of the input method. A vehicle can, therefore, be composed of components defined in a variety of ways without incurring problems with geometric compatibility provided a common system of units is used.

The typical procedure is to input a particular component, display and edit it as necessary, and then catalogue it in the permanent file. The task is repeated for each vehicle component.

Activity concerned with user controlled geometric/aerodynamic model interfaces is subsequently initiated. Typical tasks involve linking of sub assemblies to form a vehicle body component and definition of surface-flap-shell paneling. The remaining aerodynamic model definitions are developed under automatic directive.

A common geometric data base is used to develop the subsonic-supersonic and hypersonic aerodynamic models. It can be reused since it is not altered during analysis model definition.

User configuration of the system is initiated by reviewing the display, edit, units, and file title defaults and changing the directives as desired. The ATTRIBUTE and TITLE commands of section 6 are used for this purpose and provide the following prompts.

OK
→→ attribute

PRESENT USER DEFAULTS:

FILE OPERAND FOR SEVERAL COMMANDS---->: PERMANENT
ANGLE OPERAND FOR DISPLAY COMMAND----->: YAW=90.00 PITCH=0.0 ROLL=90.00
UNIT OPTION FOR DISPLAY COMMAND----->: METERS
VIEW OPERAND FOR DISPLAY COMMAND----->: THREE VIEW
LINE TYPE OPTION FOR DISPLAY COMMAND->: STICK
VIEW OPERAND FOR EDIT/LIST SUBCOMMAND>: FULL DISPLAY

ENTER: "CR" - NO CHANGE
1 - FILE OPERAND
2 - ANGLE OPERAND FOR DISPLAY COMMAND
3 - UNIT OPTION FOR UNITS COMMAND
4 - VIEW OPERAND FOR DISPLAY COMMAND
5 - LINE TYPE OPTION FOR DISPLAY COMMAND
6 - VIEW OPERAND FOR EDIT/LIST SUBCOMMAND

→→ <CR>
OK
→→ title
PRESENT TITLE IS: APAS SAMPLE SESSION GEOMETRY FILE
ENTER: NEW TITLE OR "CR"
→→ <CR>
OK

Interrogation of the various ATTRIBUTE options provide the following menu.

- ¹ENTER: 1 - PERM, 2 - LOCAL, OR 3 - COMP
- ²ENTER ANGLES: YAW, PITCH, ROLL
- ³ENTER: 1 - METERS, 2 - INCHES, OR 3 - CENTIMETERS
- ⁴ENTER: 1 - ORTHOGRAPHIC OR 2 - THREE VIEW
- ⁵ENTER: 1 - HIDDEN PANEL OR 2 - STICK FIGURE
- ⁶ENTER: 0 - FULL DISPLAY, 1 - SUPPRESS PRINT, OR 2 - SUPPRESS DISPLAY

COMPONENTS

A component in APAS is defined as an object which can be spatially defined using a set of similar concatenated cross-sections. Geometric and analysis components are used. The former approximates a portion of the physical vehicle. Analysis components are simulations of geometric components or specialized constructions. Examples are slender bodies and interference shells respectively.

A cross-section of a component is, in general, an ordered set of points which, when connected, will form a closed area either by nature of the points themselves or by the symmetric and reflection properties of the component illustrated in table 1. The component symmetry/reflection codes are assigned during digitizing and can be changed by using the EDIT/PARAMETER subcommand.

Numerically-similar points on each cross-section are connected. Point one of section one is connected to point one on section two and so, providing a simple and convenient three-dimensional component construction.

There are five basic components used in APAS. They are bodies, surfaces, slender bodies, interference shells, and field points. A description of each follows.

GEOMETRIC

Bodies (Types 1 and 2)

A body refers to a geometry construction whose primary function is to provide containment volume in a configuration. The fuselage (or major pieces thereof), nacelles, auxiliary fuel tanks, and engine pods are body components. Type 1 bodies are aircraft centerline components. The SLENDER command is the only command in APAS which makes use of the distinction between type 1 and 2 bodies.

Surfaces (Types 3 and 4)

A surface is a component such as wings, verticals, strakes, canards, horizontals, and ventrals. The distinction between types 3 and 4 is whether the reference planform is based on the root-to-tip area (type 3), such as a vertical or a ventral, or on the full trapezoidal area (type 4), as in a wing or horizontal. See figure 3-2.

Each airfoil of a surface component must start and end at the leading edge. They usually have two segments. If a surface has a blunt trailing edge, segment two will be the trailing edge, and the lower surface will be segment three. A surface with only one segment is permitted (see figure 3-3) and can be used to represent a zero thickness camber plane.

Table 1. Component Symmetry Parameters.

_____ Stored boundary

----- Generated by symmetry directive

Codes

{ 1 Non-reflective } About aircraft
2 Reflective centerline

{ + Asymmetric } About component
- Symmetric centerline

Reflective Asymmetric

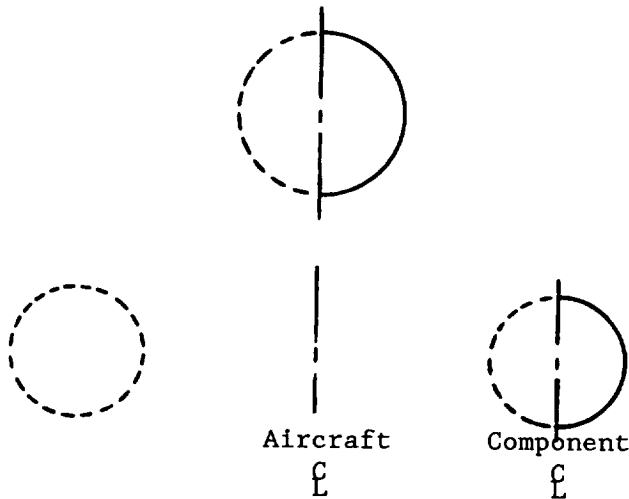
Code = 2

Example: Fuselage
Fuselage-Nacelles

Reflective Symmetric

Code = -2

Example: Missiles
Podded Nacelles



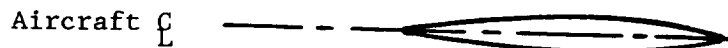
Aircraft \mathcal{C}

Component \mathcal{C}

Non-reflective Asymmetric

Code = 1

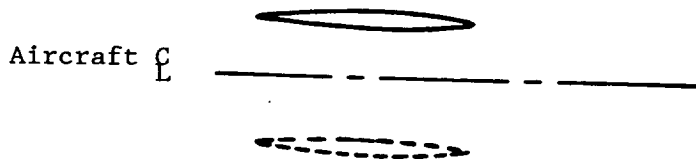
Example: Centerline Vertical



Reflective Asymmetric

Code = -2

Example: Winglets or
Twin verticals



Aircraft \mathcal{C}

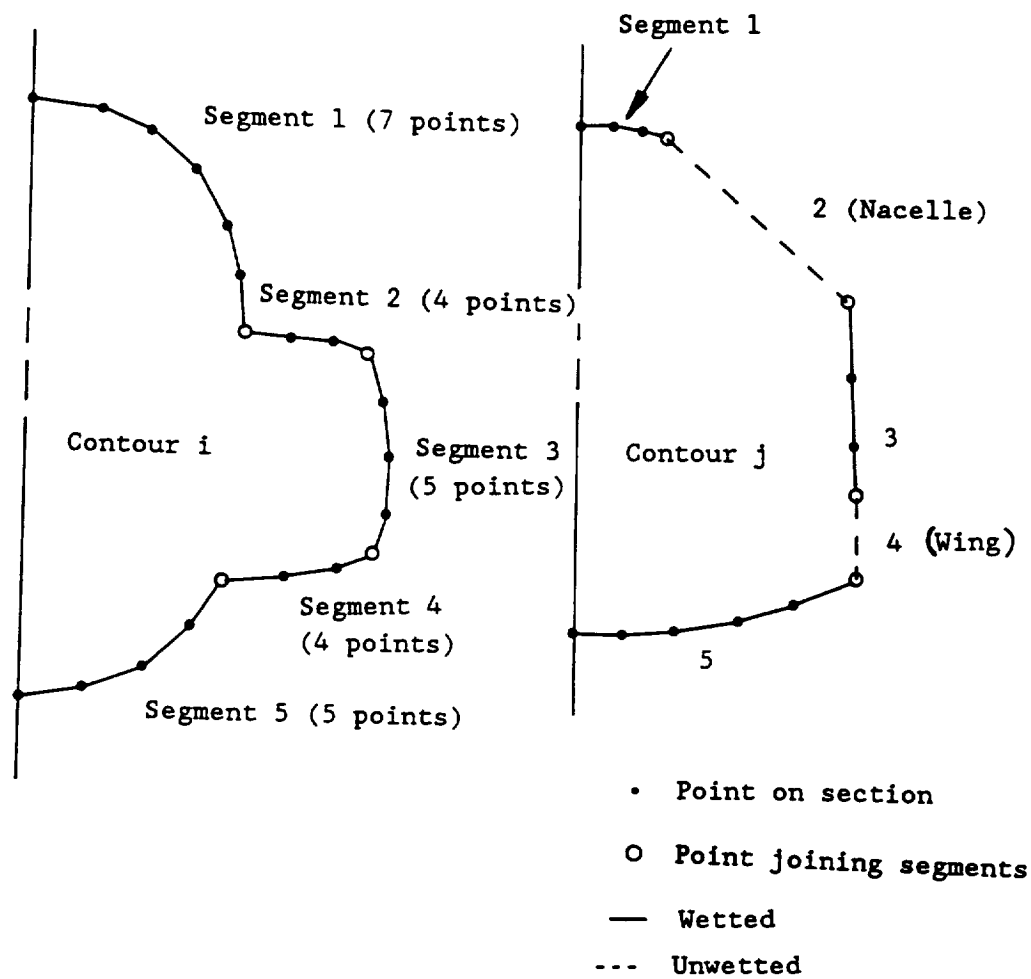


Figure 3-1. Cross-section Segmentation.

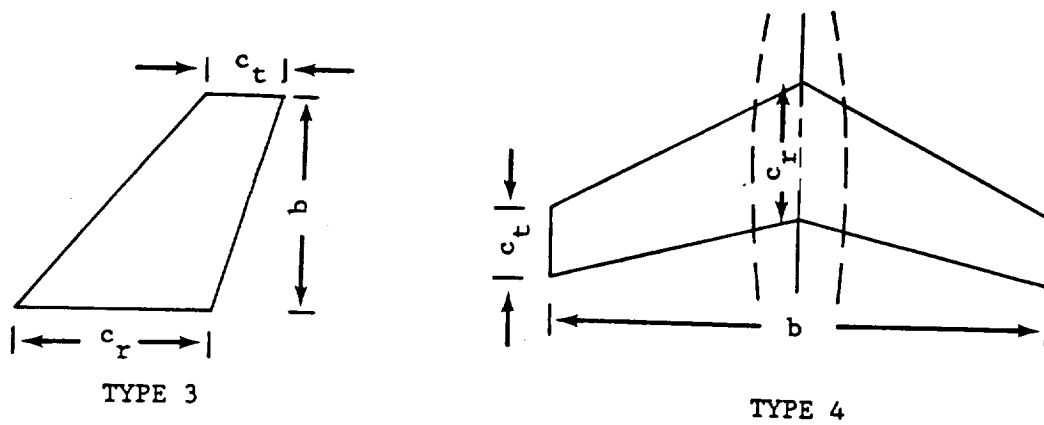


Figure 3-2. Surface Components.

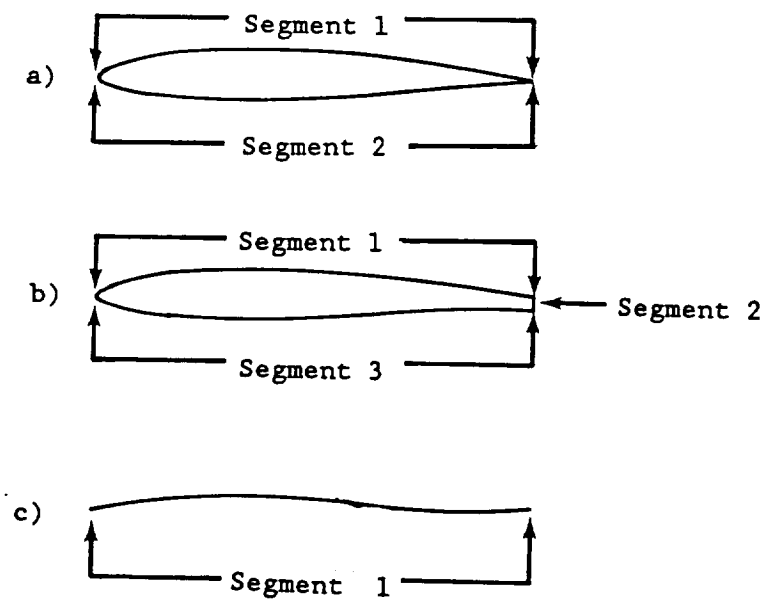


Figure 3-3. Airfoil Segmentation.

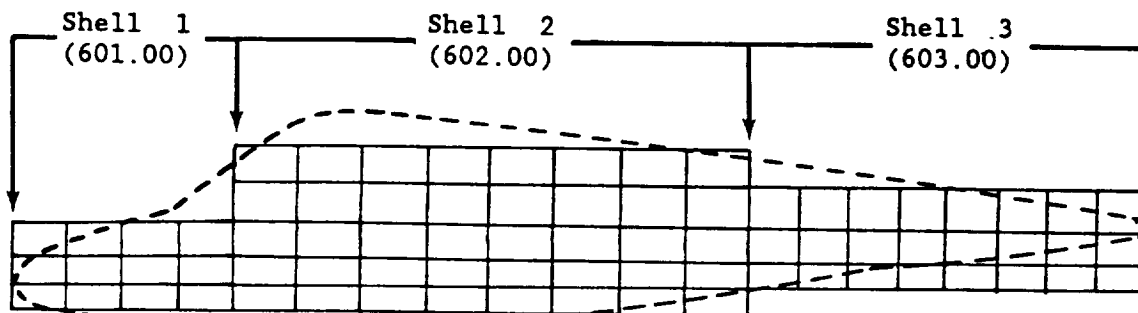


Figure 3-4. Multiple Interference Shells Use.

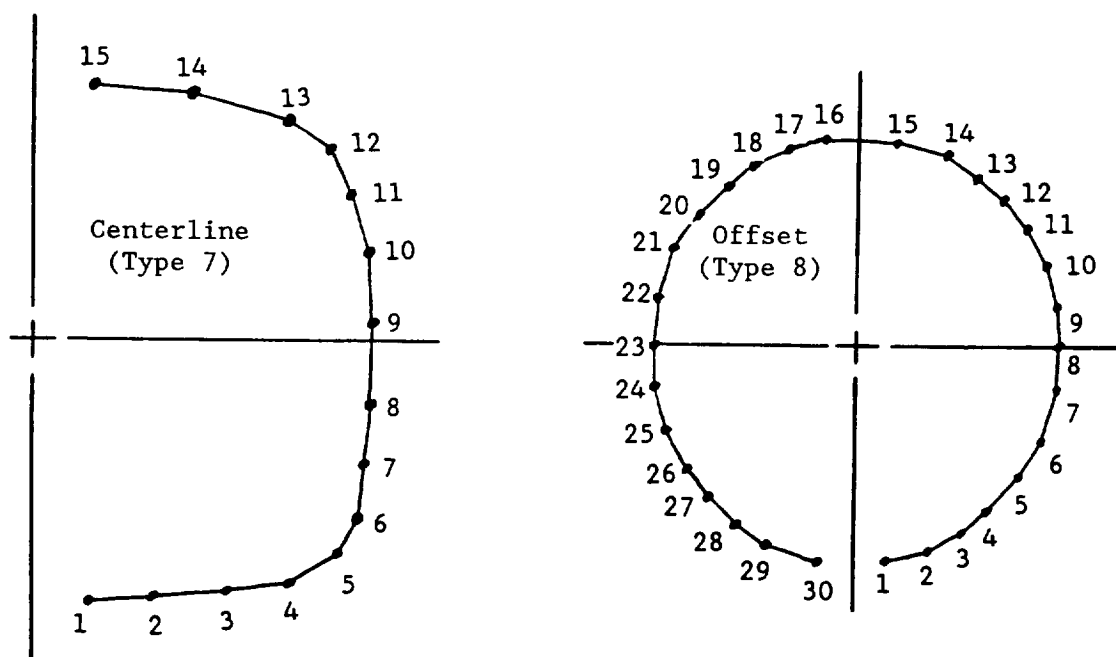


Figure 3-5. Typical Slender Body Cross-sections.

ANALYSIS

Interference Shell (Type 5)

This component is one of the special analysis constructions used in APAS. It is required with a slender body to account for carryover loads induced on the body by adjacent components. This construction is not required if a flat plate simulation of a body is used.

Interference shells are constructed using the INTERFERENCE command. They are one segment non-circular cylinders and are formed by use of symmetry parameters or closing the construction on itself. By concatenating two or more shells, figure 3-4, longitudinal variations in body cross sections can be accommodated. Each shell section must have a contour point where an adjacent surface attaches. An automatic tolerance matching procedure is provided to make the connection. Multiple interference shells are numbered consecutively from the associated body starting with the most forward shell component. They do not have to follow the slender body mold lines exactly and may penetrate the slender body.

Slender Bodies (Types 7 and 8)

This component satisfies the subsonic-supersonic analysis requirement of uniform cross-sectional point spacing and is used to simulate type 1 and 2 components. They are constructed using the SLENDER command. The merging of major pieces can also be performed to develop a contiguous component. Figure 3-5 illustrates typical cross-sections for centerline (type 7) and offset (type 8) cases. Analysis simulation of the slender body uses sources and sinks to represent the body, therefore control points approaching control points must be avoided.

An interference shell must be constructed for each slender body except for a body alone case.

Field points (Type 9)

A specified array is used to define the locations at which off-body flow conditions are desired. The CARD command is used to input up to 100 such points. Inlet analysis, missile drop simulations, etc. are typical analysis problems which make use of this option.

NUMBERING

Component numbering is used to control the order in which components are processed and the connectivity between components. It provides the user with freedom in organizing configurations, but adds the responsibility to exercise care in numbering components.

In general, components should be separated by category; i.e., bodies, nacelles, wings, verticals, etc as indicated in table 2.

Table 2. Component Numbering.

<u>COMPONENT NUMBER</u>	<u>COMPONENT TYPE</u>
10.00 - 99.00	Bodies
100.00-199.00	Nacelles
200.00-299.00	Wings
300.00-399.00	Verticals
400.00-499.00	Horizontals/canards
500.00-599.00	Ventrals/fins
600.00-699.00	Slender body/interference shells
1000.0	External stores
9999.0	Maximum component number

Each component can be assembled from up to 9 subcomponents numbered within the same decade. The following examples are combinations which are typical.

1.	Forward Fuselage	Mid Fuselage	Aft Fuselage	Pod
	10.00	11.00	12.00	13.00
2.	Inboard Wing	Outboard Wing		
	200.00	201.00		
3.	Slender Body	Interference Shell		
	600.00	601.00		

The rule for component combinations is to start the group on a multiple of 10 (the values zero through nine not being valid). The most forward or inboard subcomponent is placed first, followed by the next outboard, or aft subcomponent. By following a logical numbering system, the user will find managing his geometry file easier and also useable by others.

CONFIGURATIONS

A set of components comprising a complete vehicle definition for analysis is defined as a configuration. A geometry file may contain more than one configuration, and a given component may be used to assemble more

than one arrangement. As an example, the file listing of figure 3-6 contains two configurations shown broken out to the right.

PERMANENT GEOMETRY FILE		CONFIGURATION 1	
NUMBER	NAME		
11.00	FORWARD FUSELAGE	11.00	FORWARD FUSELAGE
12.00	AFT FUSELAGE	12.00	AFT FUSELAGE
200.00	WING 37.16 SQ M	200.00	WING 37.16 SQ M
210.00	WING 41.81 SQ M	300.00	VERTICAL
300.00	VERTICAL	400.00	CANARD 9.29 SQ M
400.00	CANARD 9.29 SQ M	600.00	SLENDER BODY
410.00	CANARD 12.08 SQ M	601.00	INTER. SHELL
600.00	SLENDER BODY		
601.00	INTER. SHELL		

CONFIGURATION 2	
11.00	FORWARD FUSELAGE
12.00	AFT FUSELAGE
210.00	WING 41.81 SQ M
300.00	VERTICAL
410.00	CANARD 12.08 SQ M
600.00	SLENDER BODY
601.00	INTER. SHELL

Figure 3-6. Two Configurations from a Single Geometry File.

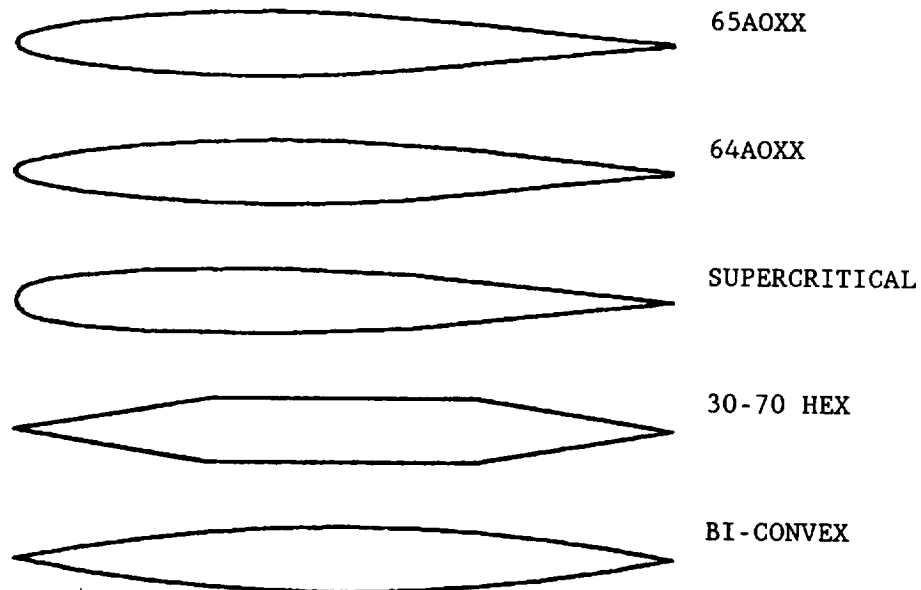


Figure 3-7. TERMINAL Airfoil Sections Command.

INPUT

Five avenues of geometry input are available for APAS. They are: (1) keyboard entry of simple shapes using the TERMINAL command, (2) digitizing arbitrary shapes from three-view configuration drawings using the DIGIT command, (3) card image data of simple or arbitrary shapes defined in accordance with appendix A and read in using the CARD command, (4) permanent geometry file which has been created using APASIN procedure and (5) permanent geometry file from a data base manager (such as GEOMOD, or Rockwell's IDAS, etc) which has an interface with APAS.

SIMPLE

The TERMINAL command allows the user to define simple geometries by typing basic descriptive parameters into the system.

Body components (types 1 and 2) are input by selecting control points (e.g. pilot station, engine face, and base) and specifying the x-station, cross-sectional area and the section width to height ratio. One segment full ellipse, half ellipse, rectangular, and triangular contour options are available.

Surface components (types 3 and 4) are input by defining aspect ratio, area, taper ratio, sweep, and dihedral. The analyst then specifies the wing section (five different types, figure 3-7) and the root and tip thickness ratio.

The CARD command provides an alternate means of inputting simple vehicle geometry. Components are constructed from similar type of data as TERMINAL, except that the user has greater control of section locations and, in the case of surfaces, upper and lower surface contours. A complete description of CARD input is provided in appendix A.

ARBITRARY

Digitizing requires a limited amount of information keyed in by the operator. The majority of the data is defined using a graphic tablet and digitizing pen. A component is constructed by sequentially digitizing a series of sections, starting from the nose and proceeding to the tail for a body or from root to tip for a surface. Adding or replacing sections on an existing component does not have an order restriction.

The following discussion is intended to provide a detailed example of how to use the DIGIT command. Reference to the command dictionary in section 6 will be helpful. The process begins by choosing a reference point for the body cross-section(s), which is usually taken as the configuration fuselage reference line (FRL), figure 3-9. Offset components can be digitized using a component reference line (CRL) and positioned relative to the configuration using the component origin, X0, Y0, Z0. Entering the reference point is step I in digitizing a body section. Step II digitizes points around the section, starting at the top of the section and working outboard around to the bottom of the section for a type 1 (centerline) component or back to the top point for a type 2 (offset) component. Segment joining points are specified (figure 3-8, section 1) by double point. If more than two segments converge at one location (figure 3-8, section 2), a point is entered for each segment. A total of five is required for this case.

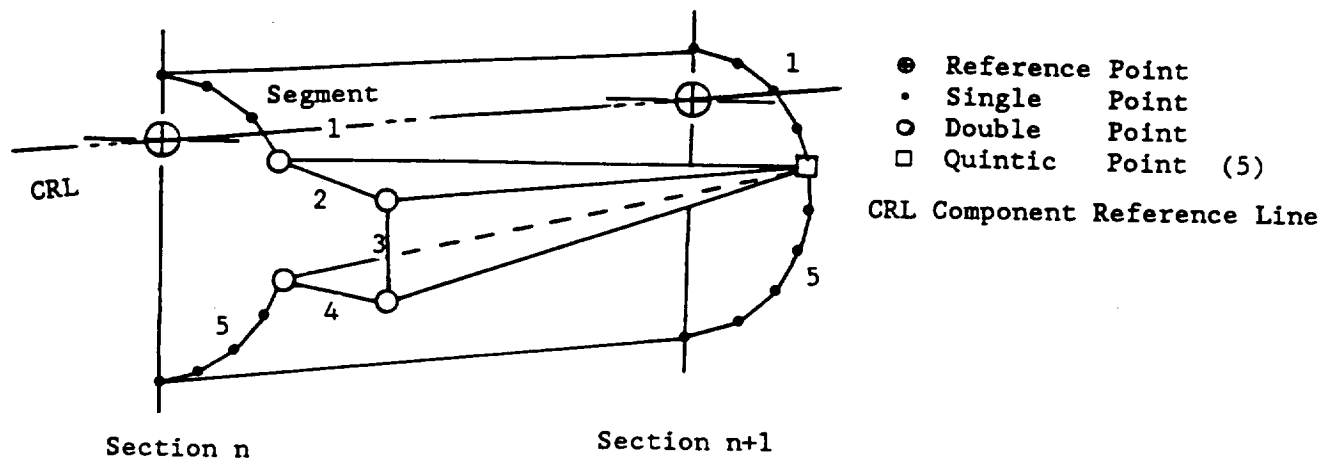


Figure 3-8. Digitizing Points for Sections Having Converging Segments.

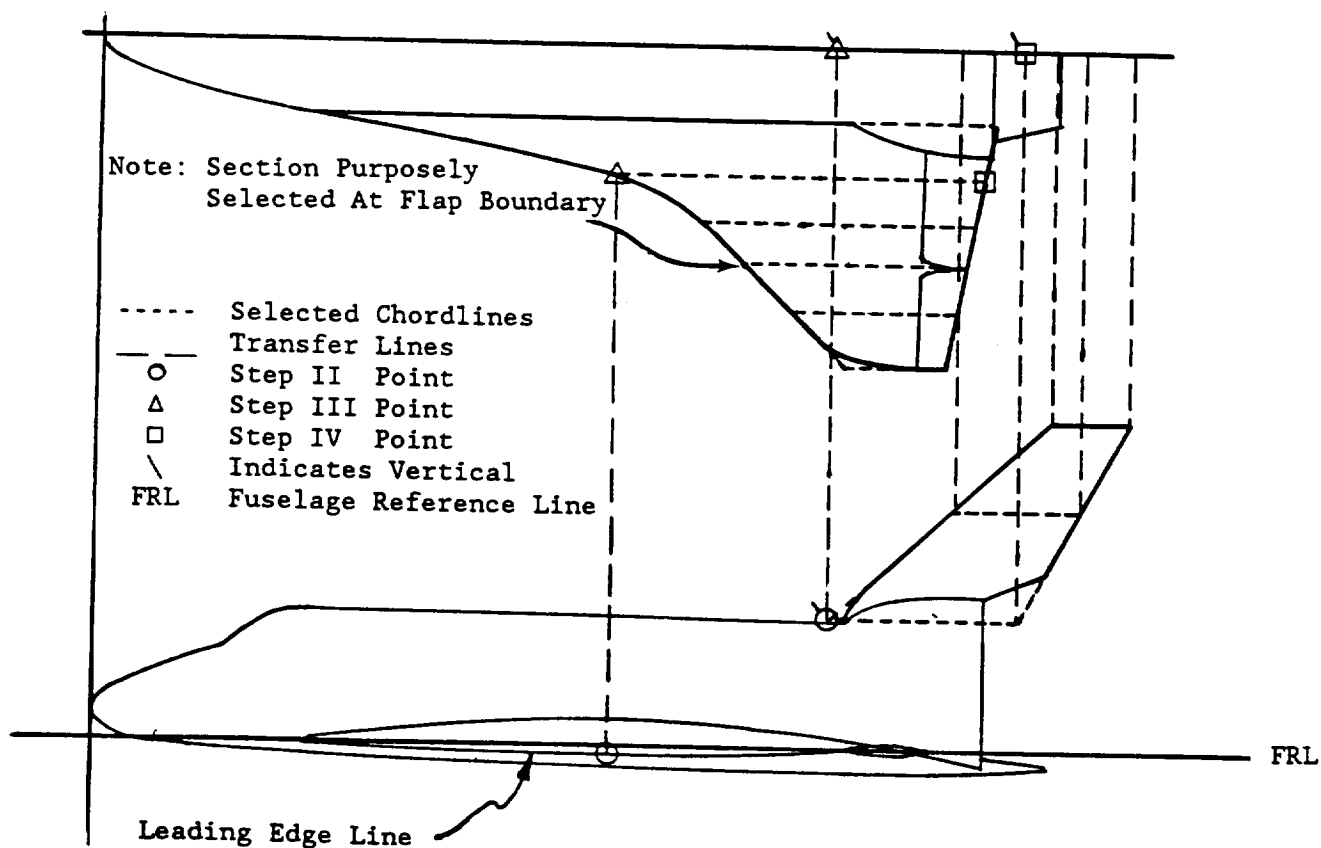


Figure 3-9. Preparing Surfaces for Digitizing.

At the end of each section digitizing, an entry from the keyboard is required to end the section. If the user has made a mistake, he can enter the letter R and carriage return, and the input will reset back to step I. If the letter S is entered, the section ends normally, the section is displayed on the screen, and the reference coordinates X0, Y0 and Z0 are printed. If the user enters the letter S, Y, or Z, the current X0, Y0, and Z0 from digitizing is printed on the screen, and the user has the option of accepting these or entering his own values. This ends the section loop. The user is asked to re-enter the section, enter a new section, or end the component.

Surface definition has two levels of input complexity. The lowest is based on the use of scaled airfoils from a 65A0XX default section or scaling an input section for the surface. The user defines the planform by entering a sequential set of section maximum-thickness ratios, origins, and chord lines. This is a repeated four step process for the default or preselected section and a seven step process for the digitized section option. The basic (four-step) process is:

- Step I: Enter maximum thickness (t/c_{max}) ratio from the keyboard. A positive t/c_{max} will scale the default or previously input section zero t/c_{max} or carriage return will return a section of the same t/c_{max} . Negative t/c_{max} activates the airfoil digitizer mode. The input section will be scaled to the chord length input in steps III and IV. If the t/c_{max} of the digitized section differs from the absolute value keyed in by more than 15 percent, the digitized thickness ratio is then scaled such that t/c_{max} matches the keyed-in value. This option allows the user to digitize standard airfoil sections.
- Step II: After entering t/c_{max} , the tablet will be initialized, and the user will enter the z or height location of the chord line from the side view of the configuration drawing. (see figure 3-9)
- Step III: The next point to enter on the chord line is the X-Y location of the leading edge. This is entered from the top view on the configuration drawing. This is visually straight forward for a wing or horizontal. The points in steps III and IV are also entered from the top view for a vertical surface end. In this case, it is helpful to draw the chordlines to be used in a vertical surface in the side view then transfer the end points onto the top view for digitizing. (See figure 3-9).
- Step IV: The final point defines the chord length (trailing edge) of the chord line. All surface chord lines run parallel to the X-axis in APAS. The leading edge of a surface has been arbitrarily selected to define the chord line reference plane.

This completes the surface section loop. In summary, step I enters t/c_{max} , step II digitizes the Z leading edge, step III digitizes the X-Y leading edge, and step IV digitizes the X trailing edge. This process is sequentially repeated from the root to tip.

If the t/c_{max} entered in step I is negative, three additional steps are performed, and a true view of each airfoil desired is required. It does not have to be the same scale as the configuration drawing. A larger scale is preferred for improved digitizing accuracy. The sections do not have to be oriented on the tablet in any particular manner because steps V and VI will define the true reference system of the airfoil.

Step V: Digitize the leading edge on the section reference line. (See figure 3-10, left side.) This point establishes the vertical location of the section. It is also an axis point for orienting the section in its true X-Z viewing space.

Step VI: Digitize the trailing edge point on the section reference line. (See figure 3-10, right side.) This point locates the axial trailing edge location for scaling the section chord to match the chord line. It is also the second point for orienting the section in its true viewing space.

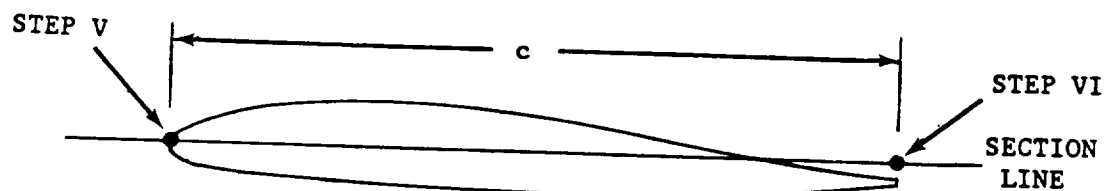


Figure 3-10. Airfoil Reference Line.

Step VII: Digitize the airfoil chordwise by starting at the leading edge. At the trailing edge, a double point is entered (for a two-segment surface) to indicate the segment brake between the upper and lower surfaces. For a blunt trailing edge (three-segment surface), a double point is entered at both trailing edge points. If a blunt trailing edge ceases to exist at a given section, a triple point is required to indicate a null segment at the trailing edge. The user then enters eight an R (to repeat steps V through II only) or an S (to end the section normally) and carriage return from the keyboard. The section thus entered becomes the default section replacing whatever section was previously stored as the default. This is the end of the digitized section input process. The user can return to step I for the same section, a new section, or end the component.

PROCESSING

Detailed descriptions of the mathematical formulas used in APAS geometry processing are presented in Appendix B. Point spacing may be based on constant curvature, constant fractional arc length or a combination of these algorithms. Linear, second-order, or least-squares smoothing interpolation is available.

Digitized body sections utilize a point spacing criteria based on 50% constant curvature and 50% constant fractional arc length. The hypersonic panel model uses the inputted geometry points as corner points for all the panels and the connectivity of these points to form panels is done automatically by the program.

Digitized cross-section segments are interpolated using the second-order or least-squares method. For surface sections, an algorithm is provided in the least squares method to estimate or incorporate the radius at the leading edge.

Section insertions are constructed by interpolating along common points (e.g., point 7 of section 8 to point 7 of section 9) with linear or second-order fits.

Surface camber and thickness are determined using a piecewise least-squares fit to provide smooth distributions and slopes on a grid defined by input geometry points. Linear interpolation is used to determine the panel coordinates and boundary conditions at control point locations.

DISPLAY

Three-view and orthographic visualization is available in the DISPLAY command to establish the acceptability of the geometry. Each has special features which help to locate problems. In addition to trouble shooting, these displays are used as a permanent record of the geometry for documentation purposes. Some artistic capabilities have consequently been included.

The three-view mode permits examination from the three standard angles as indicated on figure 3-11. In addition section cuts can be constructed and displayed using the graphics cursor.

The orthographic projection provides the ability to view geometry at user specified angles as indicated on figure 3-12. Windowing permits zooming in on a given area (figure 3-13) to investigate a problem or check the region more closely. A perspective capability is available to provide alternate views (figure 3-14) of a vehicle or group of components and also as an aide in generating underlays for artist renderings. A poor mans hidden panel algorithm can be activated in the orthographic projection to help define geometry problems masked by the standard stick figures. See figure 3-15.

EDITING

The EDIT command is used to correct or refine component geometry and update a vehicle undergoing development. A primitive capability exists to

alter a component so that the impact of size and shape changes on aerodynamics can be evaluated. A second principal function is to define subsonic-supersonic analysis paneling and flap boundaries.

Sections can be scaled, translated, deleted or inserted using a combination of graphics cursor and keyboard input of the type of operation desired. Additional capabilities are zooming into a problem area, multicomponent viewing, and several other graphical aids designed to improve visual editing capabilities. These cursor guided functions are combined into the EDIT/VIEW subcommand.

Alternative keyboard subcommands are provided to digitly correct, translate, scale, delete, or insert, component sections singly or in sequential groups.

The PARAM subcommand adjusts component segment parameters (wetted or unwetted), and origin values.

Surface finite-element definition required for the subsonic-supersonic analysis and control surface boundaries for the hypersonic analysis are development using the PANEL subcommand of EDIT.

Paneling of each surface construction in APAS must be performed by the user via the PANEL subcommand. Recommended default panel densities are indicated. Type 3 surfaces have five spanwise and five chordwise uniform panels. Type 4 surfaces have 10 by 10 evenly spaced panels. Interference shells (type 5) have 10 chordwise and one spanwise panel between each set of contour points.

PANEL allows the user to develop a finite element model which is generally independent of the chordwise and spanwise input geometry. The user may also specify sets of panels as control surfaces. PANEL uses a planview of the surface as its working display. The planform is partitioned into a set of regions with a specified number and type of finite elements. The spanwise region boundaries are determined by the input airfoil sections themselves or the root and tip if desired.

COMPONENT MANAGEMENT

Components are stored on a random or direct-access device, depending on the computer installation. This allows the user to work with them in a fast and efficient manner. Components are accessed in numerical order even though they are stored in the order in which they are cataloged.

File Structure

There are three geometry file catagories used in APAS. They are permanent, component, and local. All are binary geometry files and use the same storage process. The permanent file is used to store configuration geometry that is to be analyzed and is a read or write file. The component file is a read only file (and thus must already exist - usually is a modified copy of an existing permanent geometry file) and may be used in several ways. One of the most common uses is to point to another users permanent file and then copy out certain components into the permanent or

local file using the COPP command. Another use is as a storage file for commonly used component parts, such as engine pods, missiles and external tanks. The local file is used to place selected components from the permanent and/or component files for interactive analysis and/or as a configuration to be analyzed in the background mode. All components for execution must be present in the local file before using any of the analysis commands (VISC, WAVE, etc). APAS commands for component manipulation are ATTACH, CATALOG, CLEAR, COPP, COPY, DELETE, and the SAVE subcommand in EDIT.

ATTACH takes components from the permanent or component file and adds non-redundant components to the local file. CLEAR purges the local file and is useful for clearing the local file so another configuration can be entered, or as a preparation for entering the SET command if a new configuration is not to be defined.

CATALOG adds new components to a file and is used only with the SLEN, INTER and TERMINAL commands. It protects any old components with the same number.

COPY allows a user to copy a component within a file. COPP allows a component from the component or local file to be copied into the permanent file and has the same protections as CATALOG.

DELETE removes components from a file. The file must be specified. This protects the user from destroying components from the wrong file.

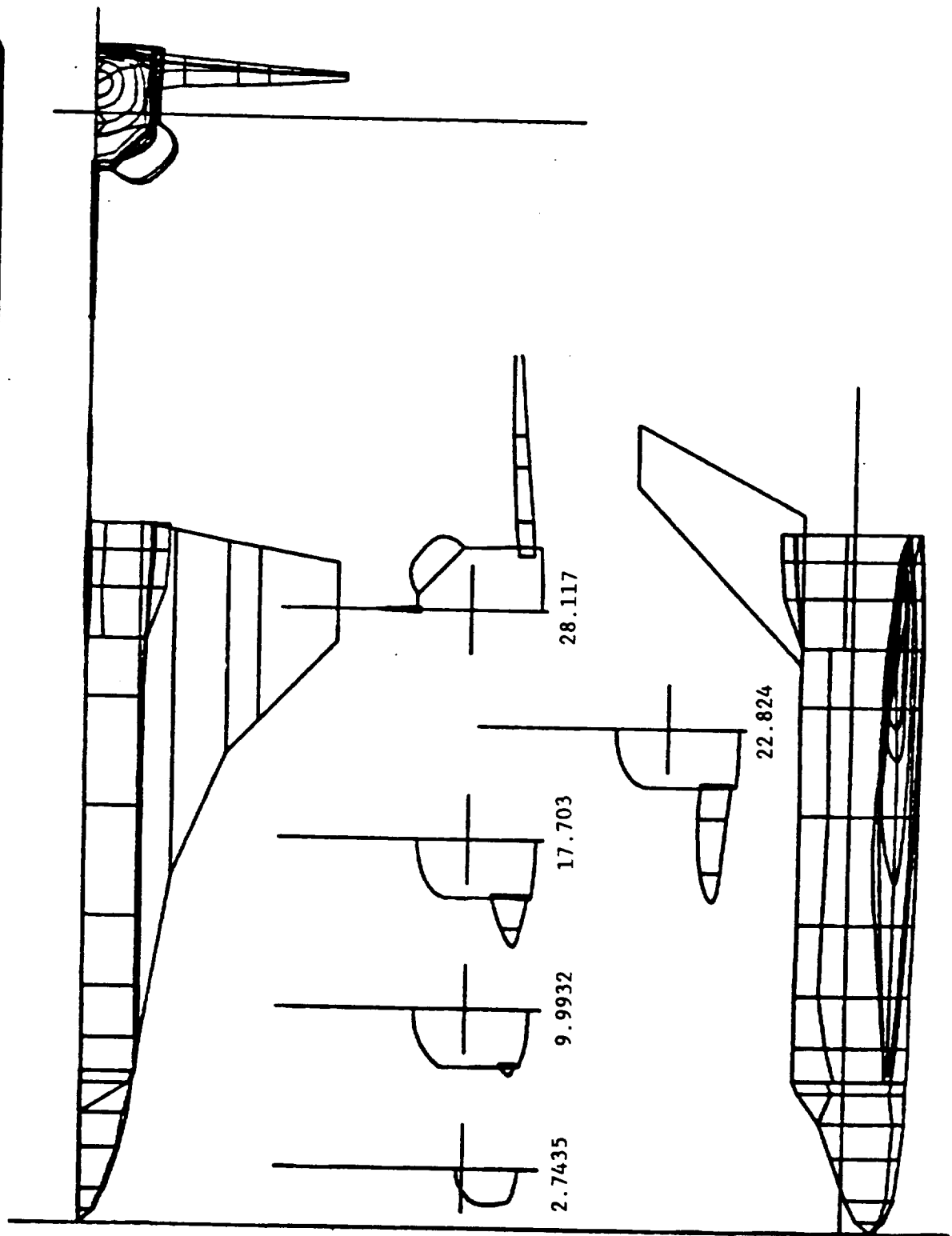


Figure 3-11. Three-view Display.

APAS SAMPLE SESSION GEOMETRY FILE

YAW	PITCH	ROLL
30.0	-30.0	0.0

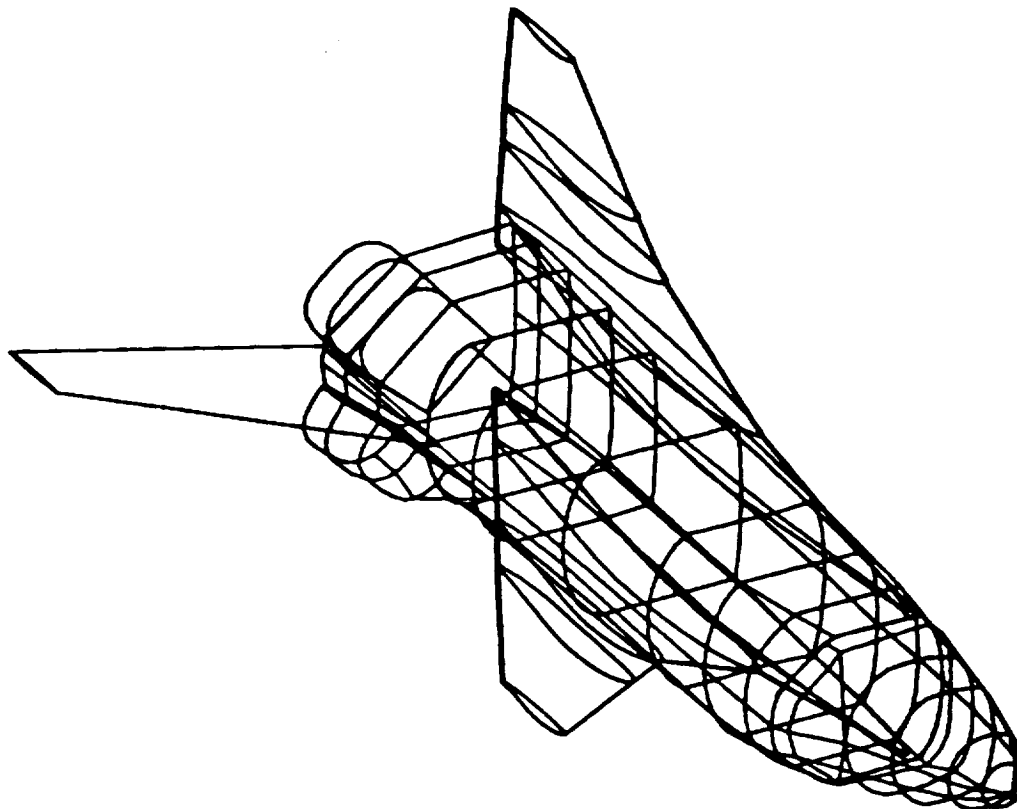


Figure 3-12. Orthographic Display.

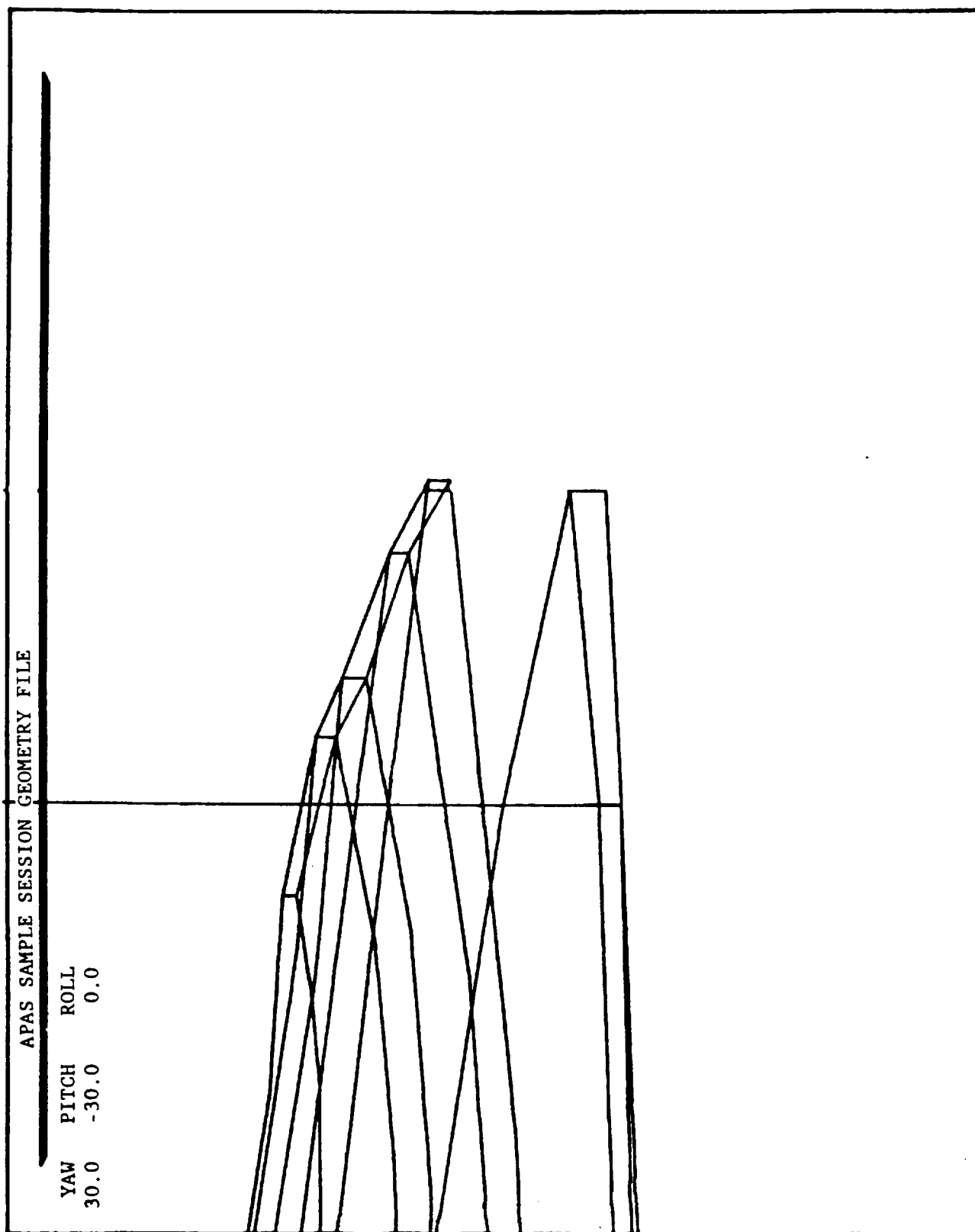


Figure 3-13. Windowing Into a Potential Trouble Area.

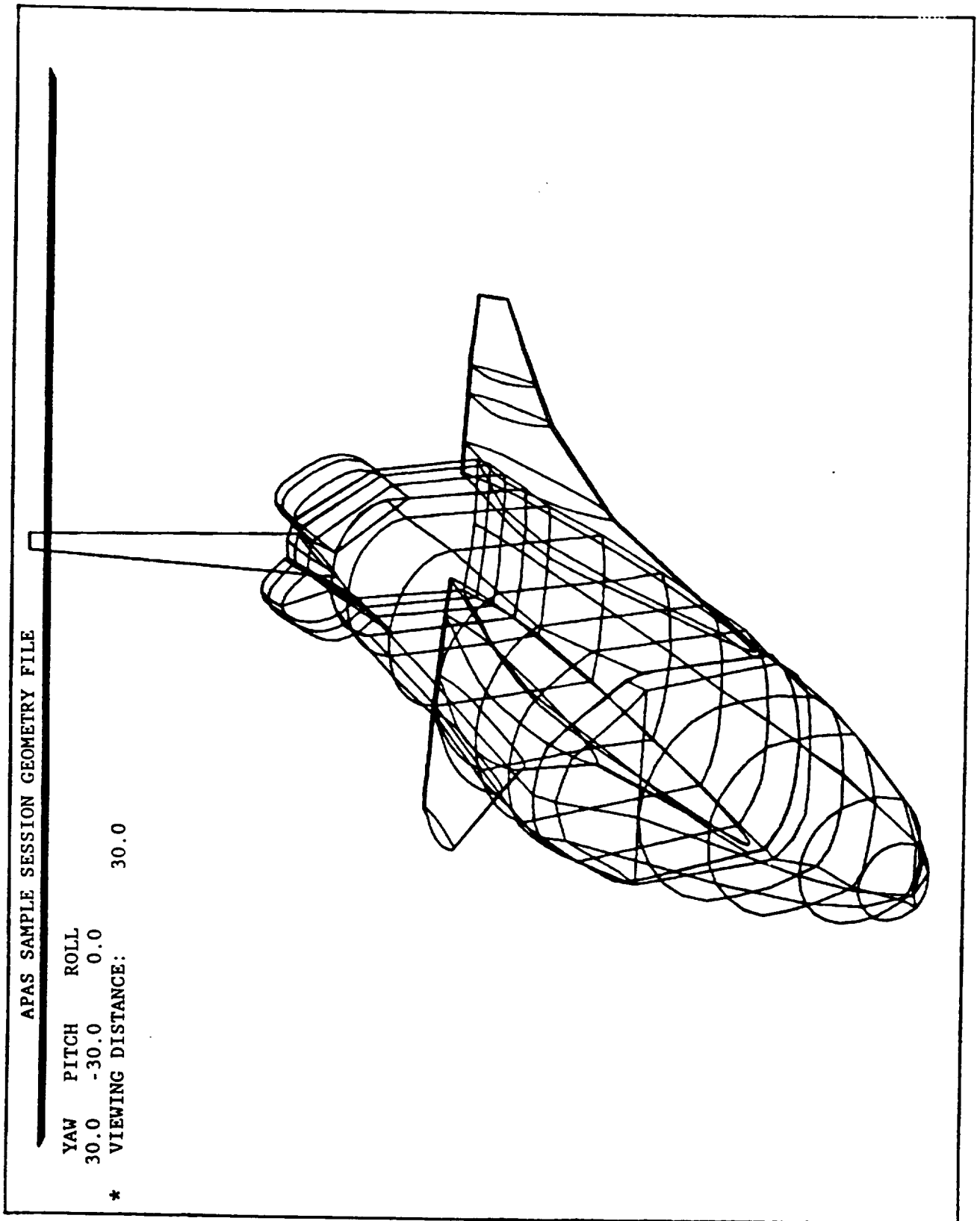


Figure 3-14. Perspective Viewing.

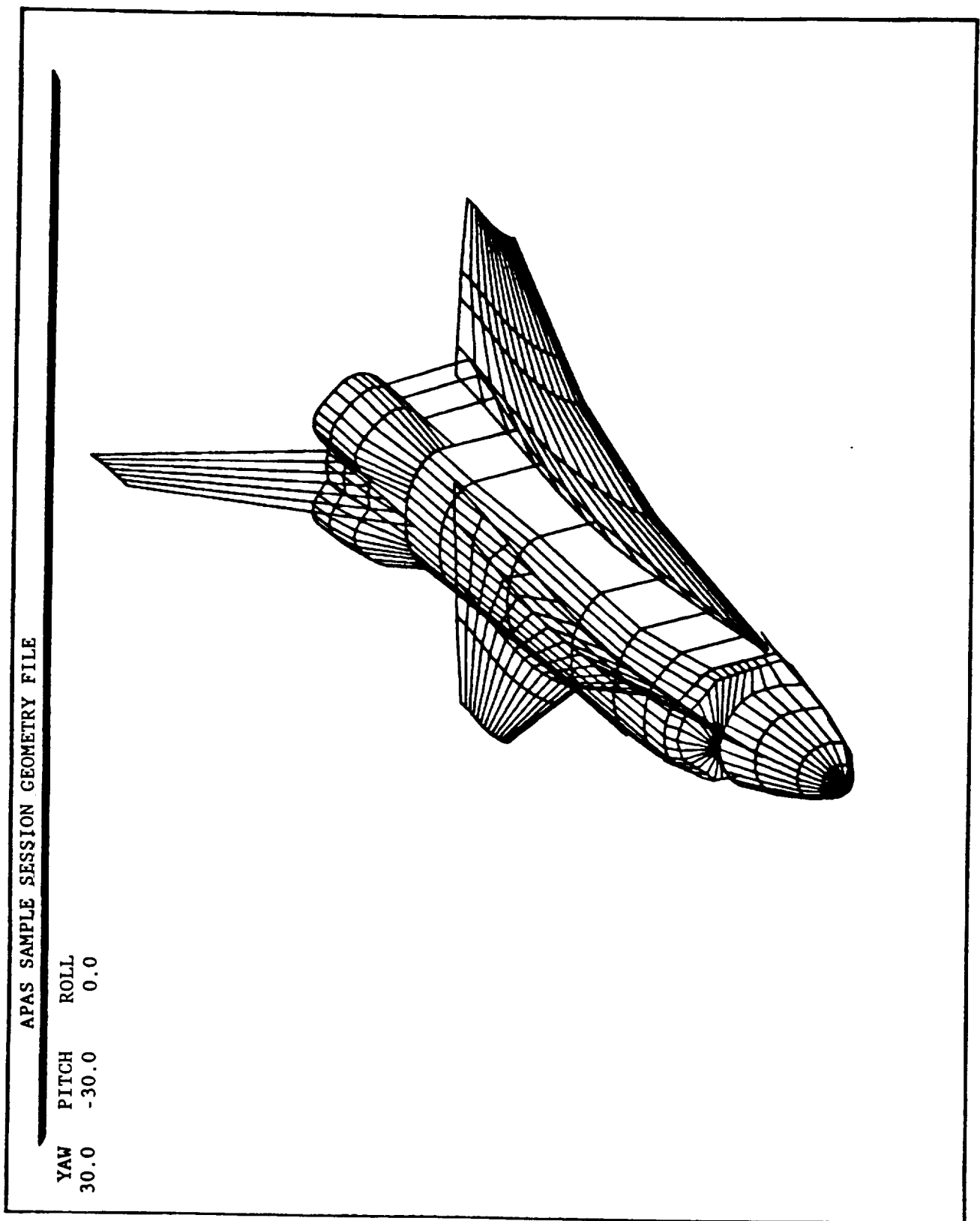


Figure 3-15. Hidden Panel Display.

SAMPLE SESSIONS

Geometry input functions are illustrated in sessions 3-1 and 3-2.

Each session is structured to illustrate a wide range of APAS capabilities. Selectively bypassing certain complexities progressively reduces the level of user expertise required, and those areas which can be delayed are pointed out in the text.

Prior to initiating any session, a preplanning effort is spent defining the specific work that will be done in order to minimize the amount of sitting time. This will assure that terminal usage is spent primarily on effort requiring the computer.

Two cases are investigated. The first case, session 3-1, a simple, conceptual vehicle which is input using the TERMINAL command. It is subsequently shaped and modified using the EDIT command and subcommands. The second case, session 3-2, digitizes the space shuttle vehicle. Differences between the two models, in terms of the type and amount of input work required, will become apparent from the discussions.

SIMPLE CONFIGURATION (CASE #1/SESSION 3-1)

Read the function descriptions of TERMINAL and EDIT in the command dictionary, section 6.

For this section, it is assumed that the gross geometric characteristics of manned recoverable space vehicle have been defined from an independent study. The data available may include a minimum cross-section area of the cargo bay, volume of crew compartment and other vehicle equipment, fuel volume required, wing and empennage size, etc. The user will define a set of geometric parameters from this data base which can be entered in APAS using the TERMINAL command to define the vehicle.

Geometric Preliminaries

Input for bodies is in the form of vehicle station, cross-section area, and width/height ratio for key locations on the body. A table of these values is set up which will be used later in APAS. Table 3 presents the pertinent fuselage information.

Table 3. Simple Body Input Data.

<u>Station (m)</u>	<u>Area (m²)</u>	<u>Width/Height</u>	<u>Description</u>
5.59	0	.88	Nose
11.68	20.65	.88	Crew station
15.24	28.39	.88	Max cargo section
33.02	30.97	.88	Max cargo section aft
38.10	43.87	.88	End of body

Surfaces are created using the parameters of planform area, aspect ratio, taper ratio, leading-edge sweep, and dihedral. The pertinent characteristics for the wing and tail are summarized in table 4.

Table 4. Simple Surface Input Data.

<u>S (m²)</u>	<u>AR</u>	<u>λ</u>	<u>Δ_{LE}</u>	<u>γ</u>	<u>Section</u>	<u>T/CR</u>	<u>T/CT</u>	<u>Surface</u>
249.91	2.3	.20	45°	3°	64AOXX	.04	.03	Wing
38.80	1.65	.40	45°	90°	HEX	.03	.03	Vertical

Additional information required for each component includes the component number and name, the origin of the component, and its orientation in space.

APAS Preliminaries

Once the configuration component geometric tabulations are complete, the user is ready to logon and run APAS. In the present case, the session is initialized using a new geometry and output file. The title of the file is entered as "APAS SAMPLE SESSION GEOMETRY FILE," screen 3-1.

The ready mode on APAS is indicated by the symbol ****OK**** to distinguish it from the normal operating mode of the computer system. The commands required to execute this session are all accessed from the ****OK**** mode. The EXIT command is used only to terminate a session.

Fuselage Input

The first component to input (using the TERMINAL command) is the fuselage because data from it will be helpful in lining-up the wing and vertical tail attachment points.

The data of table 3 are keyed in (figure 3-16) for the fuselage. Two options are available for inputting cross-section data. The number of cross sections (five in this case) were specified instead of entering all the data on one line. Note that more than one section can be entered on a line; e.g., sections 2 and 3, and that commas or blanks can be used as delimiters to separate data elements. When the last section has been entered, the maximum height and half-breadth from the centerline is printed. These characteristics will be used later for attaching surfaces to the fuselage.

The component should be cataloged immediately after it is created in order to avoid its inadvertent loss. CATALOG checks the file for another component having the same number.

The user next enters EDIT and selects the VIEW (VI) subcommand to display the fuselage, bottom of figure 3-16. If no data follow the VI command string, the default display angles for types 1 and 2 will be used for yaw, pitch and roll. Note that either upper or lower case letters may be used when typing in commands. For purposes of clarity in this document lower case inputs are used throughout.

Figure 3-17 presents the fuselage as it was created from key input. At this point, the user can accept this component and proceed to the input on figure 3-21 (text beginning on page 33) or progressively modify it on figures 3-18 through 3-20. Figure 3-18 shows the fuselage as it appears after using the graphics cursor to translate selected body sections. The menu of options is in the upper right of the screen. Options I and F interpolate the section at the location chosen with the vertical cursor. Sections can be inserted only between the nose and tail and out of the proximity of other sections. A programmed alarm will sound if an errant key is entered, or a cursor rule is violated. Options D through L are one-step functions locating the nearest section to the vertical graphics cursor on which to operate. Option D deletes that section. Options T and B scale the section vertically until the top or bottom respectively matches the Z-location indicated by the horizontal cursor. Options U and L translate the section vertically until the top (upper) or bottom (lower) respectively matches the location indicated with the horizontal cursor.

```

ENTER TITLE FOR NEW DATA FILE:
apas sample session geometry file
* * O K * *

+++ terminal
  * ENTER COMPONENT YAW,PITCH,ROLL :
+++ <CR>
    0.0    0.0    0.0  DEFAULTS SELECTED

    * 1 FULL SURFACE
    * 2 HALF SURFACE
    * 3 FULL ELLIPSE
    * +4 HALF ELLIPSE UP      -4 HALF ELLIPSE DOWN
    * 5 RECTANGLE
    * +6 TRIANGLE UP          -6 TRIANGLE DOWN
    * E END
+++ 3
  * INPUT COMPONENT NAME:
+++ simple fuselage
  * INPUT COMP NUMBER:
+++ 10
  * BODY COMPONENT
  XRO,YRO,ZRO  Note: if <CR> entered, defaults = 0,0,0
+++ 0,0,0
  * NUMBER OF CROSS SECTION OR
  * X(1),A(1),W/H(1).....X(NCS),A(NCS),W/H(NCS)
+++ 5
  * ENTER SETS OF (X,A,W/H) FOR 5 CROSS-SECTIONS
+++ 5.59 0.0. 0.88
    ?
+++ 11.68 20.65 0.88 15.24 28.39 0.88
    ?
+++ 33.02 30.97 0.88
    ?
+++ 38.10 43.87 0.88

    MAXIMUM HEIGHT ABOVE COMP. REF. LINE:      3.9836
    MAXIMUM HALF BREATH OF COMPONENT      :      3.5055
    **OK**
+++ catalog
    **OK**
+++ EDIT 10
    EDIT**
+++ vi

```

Figure 3-16. TERMINAL Input of a Simple Fuselage.

APAS SAMPLE SESSION GEOMETRY FILE

SIMPLE FUSELAGE

YAW- 0.0 PITCH- 0.0 ROLL- 0.0

MENU OF KEY FUNCTIONS

INSERT - 2ND ORDER : I
 INSERT - LINEAR : F
 DELETE : D
 SCALE TOP TO CURSOR : T
 " BOTTOM TO CURSOR : B
 MOVE UPPER TO CURSOR : U
 MOVE LOWER TO CURSOR : L
 TRANSLATE COMPONENT : M
 OVERWRITE : O
 REPAINT : R
 ZOOM - ENLARGE IMAGE : Z
 WIDE - SHRINK IMAGE : W
 END : E

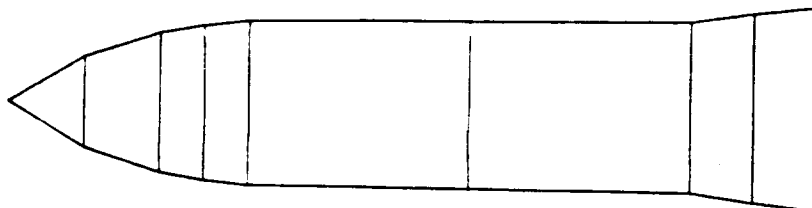


Figure 3-17. Simple Fuselage Display.

Option M translates the entire component. The cursor is positioned and the letter M is entered. The cursor is now positioned to a new location and M is entered again. A translation vector is defined with the two entries, and the EDIT component is translated and displayed in its new location.

Option O displays (overwrites) the edited component on top of the screen image already present. Option R repaints the entire screen image, including auxiliary components, if any. The cursor location at the time the Z-option is requested via the keyboard forms one corner of the window into which the user wishes to zoom in on. The cursor should next be moved to a location to form other diagonal corner of window and when Z is entered from the keyboard the box is completed and the new view displayed. Option W doubles the amount of real space viewed on the screen, leaving the EDIT component centered on the screen.

APAS SAMPLE SESSION GEOMETRY FILE

SIMPLE FUSELAGE

YAW- 0.0 PITCH- 0.0 ROLL- 0.0

MENU OF KEY FUNCTIONS

INSERT - 2ND ORDER : I
 INSERT - LINEAR : F
 DELETE : D
 SCALE TOP TO CURSOR : T
 " BOTTOM TO CURSOR : B
 MOVE UPPER TO CURSOR : U
 MOVE LOWER TO CURSOR : L
 TRANSLATE COMPONENT : M
 OVERWRITE : O
 REPAINT : R
 ZOOM - ENLARGE IMAGE : Z
 WIDE - SHRINK IMAGE : W
 END : E

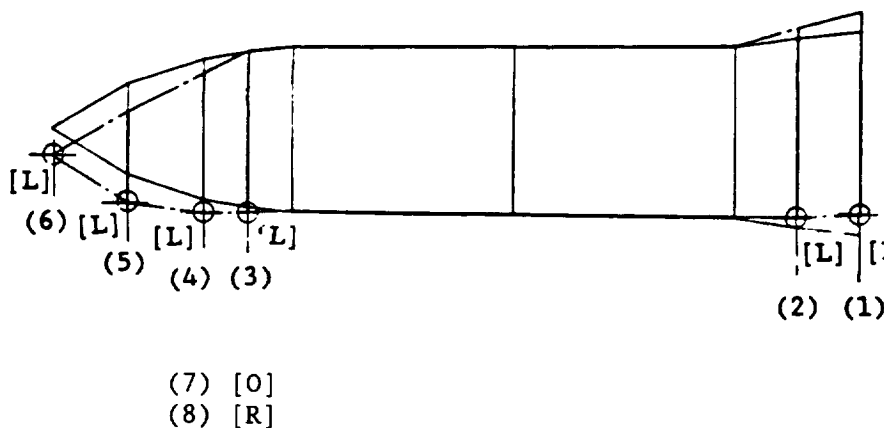


Figure 3-18. Fuselage Modification by Section Translation.

The modifications of figure 3-18 are made with the L-key to translate selected sections, forming the bottom line of the fuselage (steps 1 through 6). The changes are reviewed with the overwrite key (O, step 7), producing the single dashed display of the changes, and the screen is repainted (R, step 8).

In figure 3-19, two sections have been inserted between sections 1 and 2 and 2 and 3 of the original fuselage to improve the nose definition. A series of top scalings (T, steps 3 through 5) and a bottom scaling (B, step 6) round out the original conical nose shape. A section translation (L, step 7) corrects a small error from the previous figure. An overwrite is performed (O, step 8) to check the changes, and a repaint to view the final adjustment in figure 3-20. The user then ends the view mode (E, step 1), SAVES the fuselage (step 2), and ENDS the EDIT mode. For clarity, the last entry on figure 3-20 is repeated at the top of figure 3-21.

APAS SAMPLE SESSION GEOMETRY FILE

YAW= 0.0 PITCH= 0.0 ROLL= 0.0

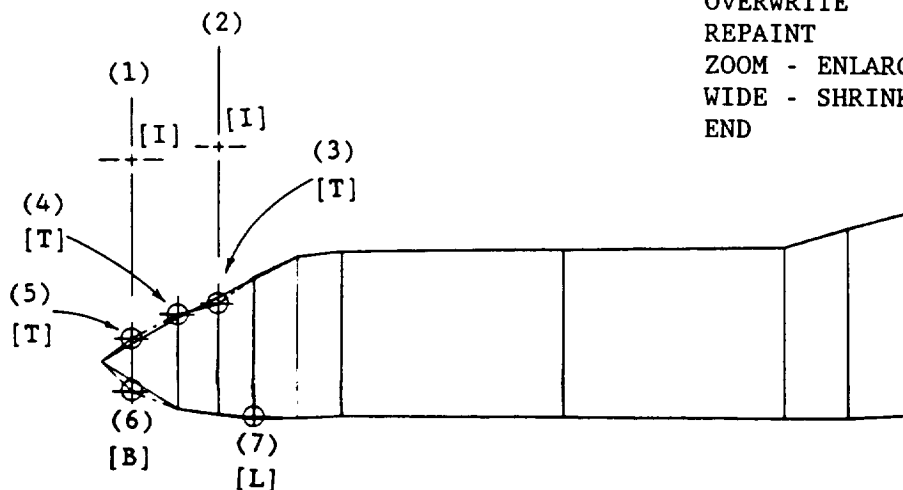
SIMPLE FUSELAGE

MENU OF KEY FUNCTIONS

```

INSERT - 2ND ORDER : I
INSERT - LINEAR    : F
DELETE            : D
SCALE TOP TO CURSOR : T
" BOTTOM TO CURSOR : B
MOVE UPPER TO CURSOR : U
MOVE LOWER TO CURSOR : L
TRANSLATE COMPONENT : M
OVERWRITE         : O
REPAINT           : R
ZOOM - ENLARGE IMAGE : Z
WIDE - SHRINK IMAGE : W
END               : E

```



(8) [O]
(9) [R]

Figure 3-19. Inserting Sections and Modifying Fuselage Nose.

APAS SAMPLE SESSION GEOMETRY FILE

YAW- - 0.0 PITCH- 0.0 ROLL- 0.0

```

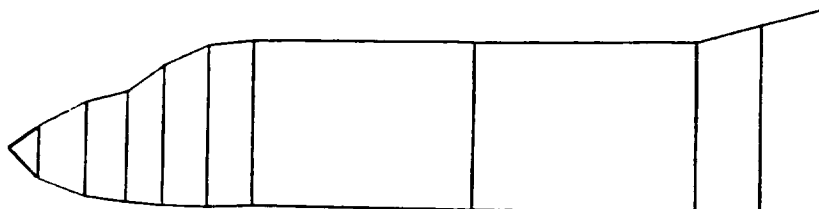
      EDIT**
(2)  →→→ save
      SAVED IN PERM FILE
      EDIT**
      →→→ end
    
```

SIMPLE FUSELAGE

MENU OF KEY FUNCTIONS

```

INSERT - 2ND ORDER  : I
INSERT - LINEAR     : F
DELETE              : D
SCALE TOP TO CURSOR : T
  " BOTTOM TO CURSOR : B
MOVE UPPER TO CURSOR : U
MOVE LOWER TO CURSOR : L
TRANSLATE COMPONENT : M
OVERWRITE           : O
REPAINT             : R
ZOOM - ENLARGE IMAGE : Z
WIDE - SHRINK IMAGE  : W
END                 : E
    
```



(1)
[E]

Figure 3-20. Viewing and Saving Modified Simple Fuselage.

Wing Input

Figure 3-21 illustrates the steps involved in constructing a simple wing from the data of Table 4, using the full-surface option of TERMINAL. Referring to the bottom of figure 3-16, use is made of the maximum half-breadth and height to initially locate the wing-fuselage lateral and vertical attachment YO(root) of 3.30 meters and ZO(root) of -3.05 meters were selected for this purpose.

```
      EDIT**
--> end
      **OK**
--> terminal
      * ENTER COMPONENT YAW,PITCH,ROLL :
--> <CR>
      0.0      0.0      0.0  DEFAULTS SELECTED

      * 1 FULL SURFACE
      * 2 HALF SURFACE
      * 3 FULL ELLIPSE
      * +4 HALF ELLIPSE UP      -4 HALF ELLIPSE DOWN
      * 5 RECTANGLE
      * +6 TRIANGLE UP          -6 TRIANGLE DOWN
      * E END

--> 3
      * INPUT COMPONENT NAME:
--> simple wing
      * INPUT COMP NUMBER:
--> 101
      * FULL SURFACE : X(CBAR/4),YO(ROOT),ZO(ROOT):
--> 33.02 3.30 -3.05
      * S,AR,TAPER,SWEEP(DEG),DIH(DEG):
--> 249.91 2.3 .2 45 3
      * 1 65 A OXX
      * 2 64 A OXX
      * 3 SUPERCritical
      * 4 HEX AIRFOIL
      * 5 BI-CONVEX
      * SELECT AIRFOIL TYPE:
--> 1
      *ENTER : (T/C)1 , (T/C)2 . . . . (T/C)M, N <=10
      (DEFAULT VALUES: 0.05,0.05)
--> .04 .03
      **OK**
--> cata
      **OK**
--> edit 101 10
      EDIT**
--> vi
```

Figure 3-21. TERMINAL Input of Simple Wing.

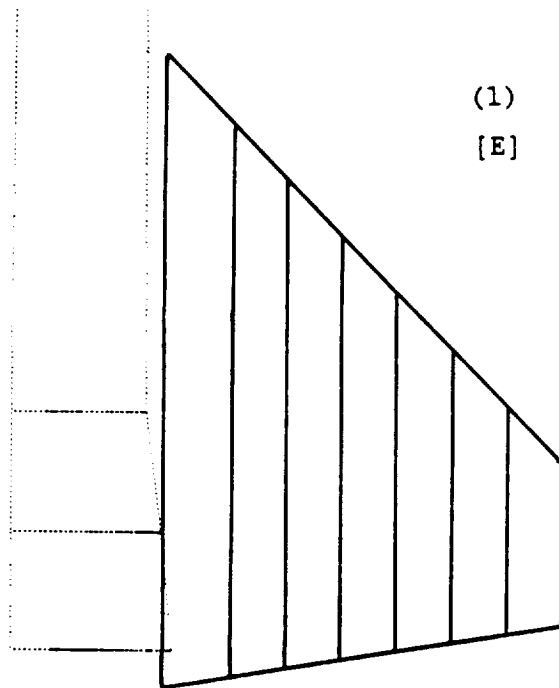
After keying in the wing and cataloging it, the EDIT command is entered for the wing (component 101.00), using the fuselage (component 10.00) as an auxiliary component. The VIEW subcommand in EDIT is selected and the work shifts to figure 3-22.

APAS SAMPLE SESSION GEOMETRY FILE

YAW= 0.0 PITCH= 0.0 ROLL= 0.0

EDIT**

(2) →→→ 1,L



SIMPLE FUSELAGE

MENU OF KEY FUNCTIONS

INSERT - 2ND ORDER : I
 INSERT - LINEAR : F
 DELETE : D
 SCALE TOP TO CURSOR : T
 " BOTTOM TO CURSOR : B
 MOVE UPPER TO CURSOR : U
 MOVE LOWER TO CURSOR : L
 TRANSLATE COMPONENT : M
 OVERWRITE : O
 REPAINT : R
 ZOOM - ENLARGE IMAGE : Z
 WIDE - SHRINK IMAGE : W
 END : E

Figure 3-22. Wing Viewing Using Auxiliary Component.

The user elects to line up the root trailing edge of the wing with the end of the fuselage. This is accomplished by the steps outlined in figures 3-22 and 3-23.

Ending the view mode (E, step 1, screen 3-7), the user lists the first section by keying the section number and the letter L (step 2). This display (figure 3-23) provides a tabulation of the airfoil coordinates for section 1. The trailing edge point should be at $x = 38.10$ meters. Its present location is at 5.891 meters (point 16) plus X_0 of 33.02 meters or 38.911 meters. To correct the wing, a DX of -0.811 meters is applied to all the stations (1,99,ALL). The user now returns to the VIEW mode (figure 3-24). To save space, the original view (figure 3-22) was widened in steps 1 and 2, and the final screen with a full view of the fuselage is shown.

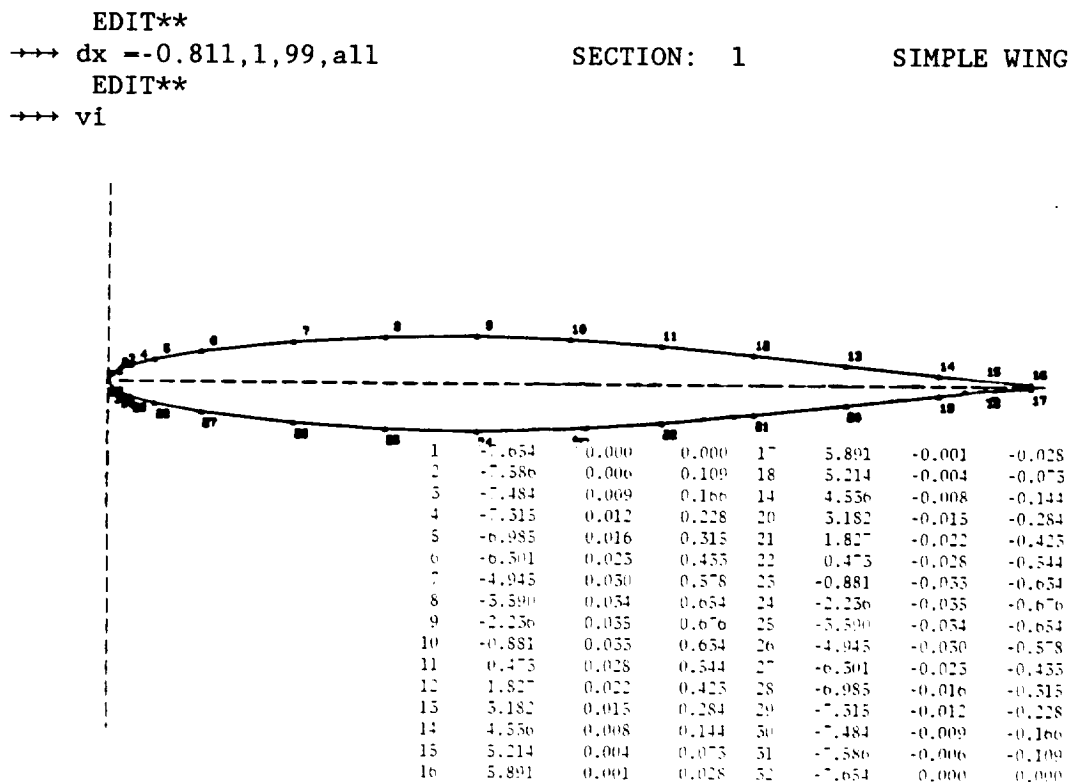


Figure 3-23. Translating the Wing.

APAS SAMPLE SESSION GEOMETRY FILE

SIMPLE WING

YAW= 90.0 PITCH= 0.0 ROLL= -90.0

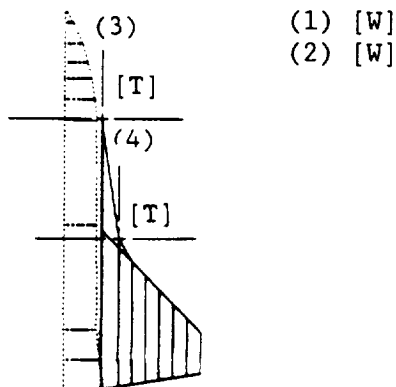
MENU OF KEY FUNCTIONS

```

      EDIT**
(7)  --- 1,dy=-0.508
      EDIT**
      --- save
      SAVED IN PERM FILE.
      EDIT**
      --- vi
    
```

```

INSERT - 2ND ORDER  : I
INSERT - LINEAR     : F
DELETE              : D
SCALE TOP TO CURSOR : T
  " BOTTOM TO CURSOR : B
MOVE UPPER TO CURSOR : U
MOVE LOWER TO CURSOR : L
TRANSLATE COMPONENT : M
OVERWRITE           : O
REPAINT              : R
ZOOM - ENLARGE IMAGE : Z
WIDE - SHRINK IMAGE  : W
END                  : E
    
```



```

(5) [O]
(6) [E]
    
```

Figure 3-24. Increasing the Viewing Space and Modifying the Wing Leading Edge.

The translate function, T, is now used to modify the wing leading edge (T, steps 3 and 4). The changes are checked using overwrite (O, step 5). Note that the root chord does not attach to the side of the body. The user ends the view mode (E, step 6) and moves the root section (section 1) inboard an estimated 0.508 meters (step 7). The work is then saved (the original component is written over), which reevaluates the wing extents since the planform has been changed. The wing is then viewed (figure 3-25) to verify the final changes. The user ends from EDIT/VIEW and produces a three-view display on figure 3-26.

APAS SAMPLE SESSION GEOMETRY FILE

SIMPLE WING

YAW= 90.0 PITCH= 0.0 ROLL= -90.0

MENU OF KEY FUNCTIONS

EDIT**
(2) →→ end
 OK
 →→ disp 101 10

INSERT - 2ND ORDER : I
INSERT - LINEAR : F
DELETE : D
SCALE TOP TO CURSOR : T
" BOTTOM TO CURSOR : B
MOVE UPPER TO CURSOR : U
MOVE LOWER TO CURSOR : L
TRANSLATE COMPONENT : M
OVERWRITE : O
REPAINT : R
ZOOM - ENLARGE IMAGE : Z
WIDE - SHRINK IMAGE : W
END : E

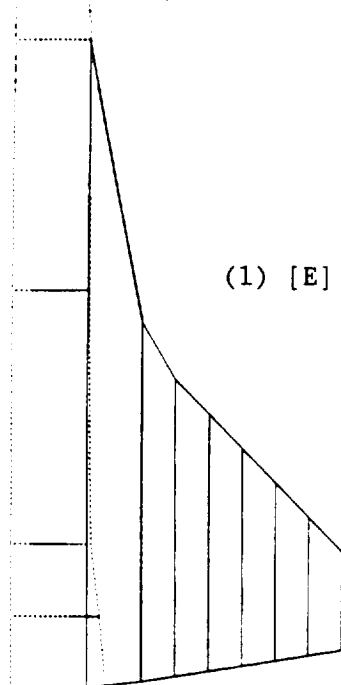


Figure 3-25. Final View of Simple Wing Modifications.

APAS SAMPLE SESSION GEOMETRY FILE

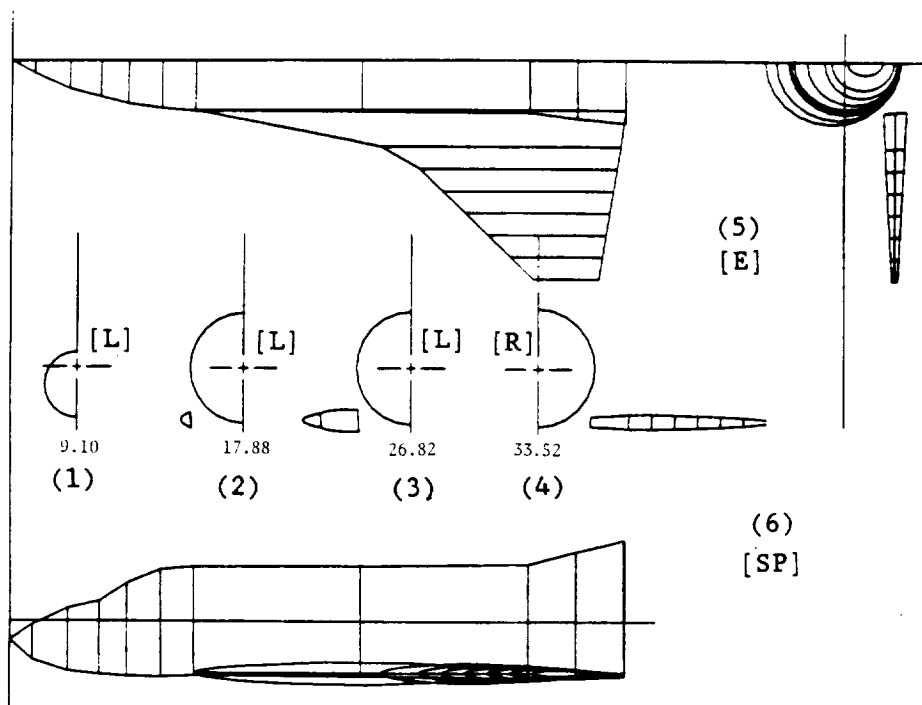


Figure 3-26. Three-view of Simple Wing and Fuselage.

Four cross-section cuts are made, three to the left (L, steps 1 through 3) and one to the right (R, step 4). Step 5 ends the cross-section mode, at which point the contours are filled in. A copy can now be taken. Step 6 returns the program to the **OK** mode.

Note the gap between the wing and fuselage in figure 3-26. The analyst decided to correct the fuselage and uses the EDIT/XH cross hairs subcommand to flatten the sides and bottom to match the wing. The cross hairs operation is a two-step process; the first entry locates the nearest point and the second its new location. Steps 1 and 2 of figure 3-27 show the translation of point 12, steps 3 and 4 move point 11, etc. for section 11. The space bar [SP] is the most convenient way to enter the point, and an [0] will end the cross hairs function either on the translate entry (step 10 for example) or the following entry as was done here.

The user lists the modified section in figure 3-28 with print suppressed and uses the cross hairs to readjust points 8 through 12 slightly (not illustrated). The final section is shown in figure 3-29. A print suppressed listing of section 10 is now requested (figure 3-30). The user now realizes that a simpler method to accomplish the same results at section 11 are the first two entries on figure 3-30. In the first entry, the z-values at points 8 through 13 were set equal to the z at point 13.

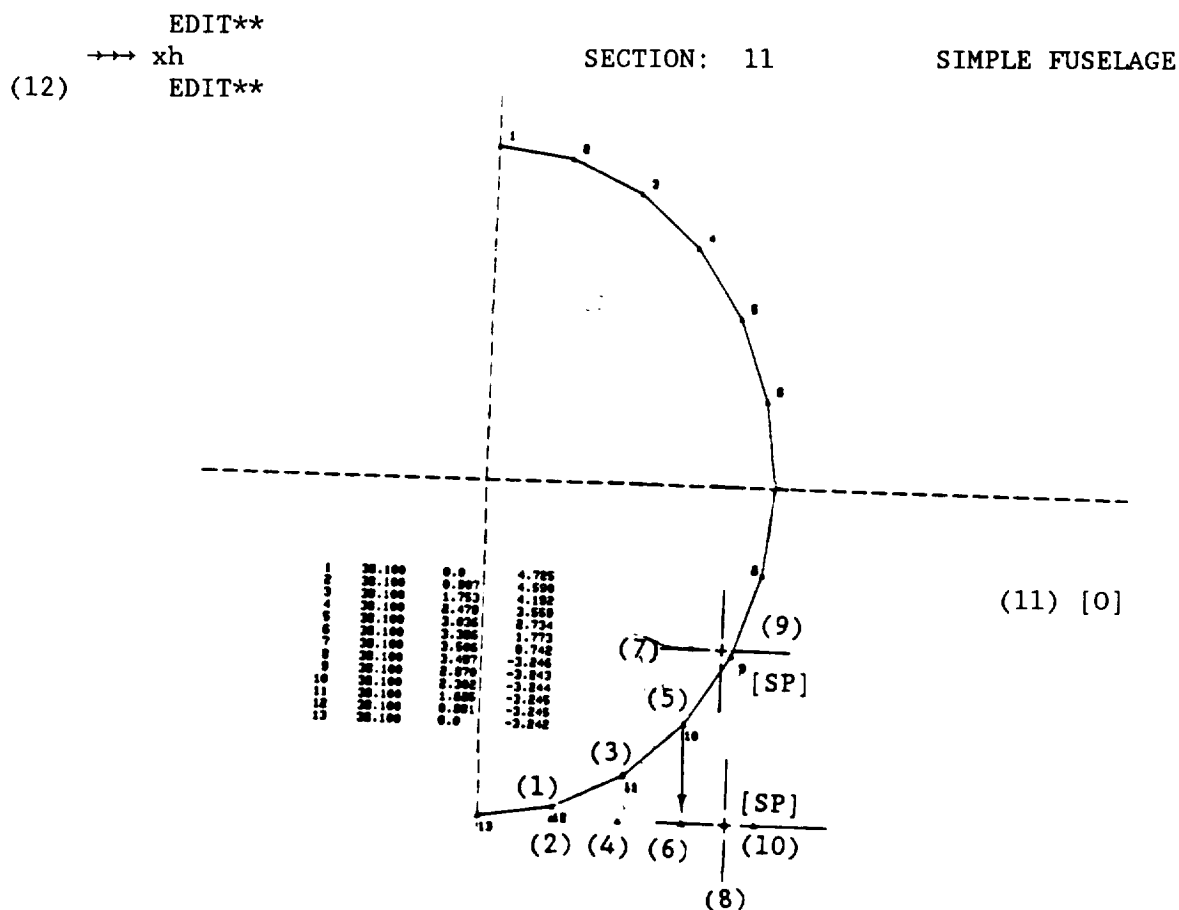


Figure 3-27. Modifying a Fuselage Section Using the EDIT/XH Cross Hair Subcommand.

EDIT**
→→→ xh
EDIT**
→→→ l, sp

SECTION: 11

SIMPLE FUSELAGE

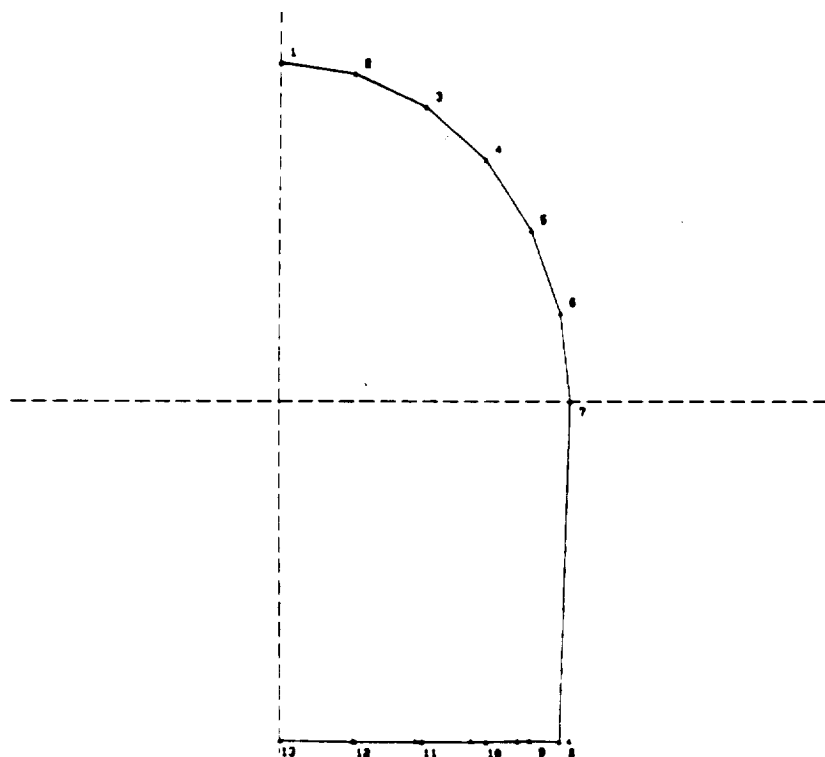


Figure 3-28. Modified Cross-section from Figure 3-27.

EDIT**

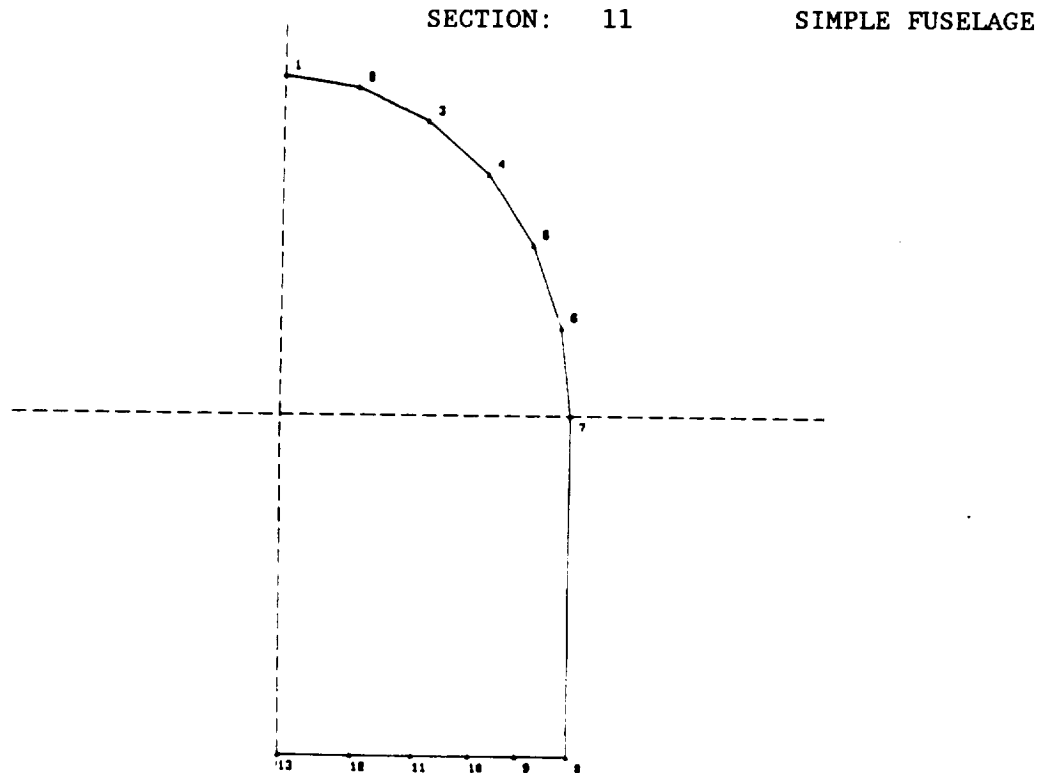


Figure 3-29. Final View of Modified Cross-section.

In the second entry, the y-value of points 8 through 8 were changed to the y at point 7. The resulting section modification is displayed on figure 3-31. Four additional (sections 6 through 9) modification entries are shown on figure 3-31. Section 6 is listed on figure 3-32 and the cross hairs mode is used to move points 8, 9 and 10 (arrows, bottom of section) to round off the lower corner. On figure 3-33 the z-value of point 10 is matched to point 11 to make sure the bottom is flat. The user then saves the fuselage and ends edit. The final entry on figure 3-33 is to obtain an orthographic projection of the components (no components listed) at angle 0 for yaw, pitch, and roll. A view from the nose is shown on figure 3-34.

On figure 3-35, the user has displayed the wing and fuselage interface. It is decided to move the wing up one-half the root chord maximum thickness to improve the intersection (figure 3-36). By using the PARAMETER (P) subcommand in EDIT, the user increases the wing z origin by 0.686 meters. In the parameter mode, carriage return retains the old values, and the user enters a carriage return until prompted for the origin input (fifth arrow). To adjust only Z0, he enters a comma to keep X0, a comma to keep Y0, and the new Z0 value of -2.362 meters. The wing is saved, EDIT is ended, and a three-view display of all components in the permanent file (the user's default file) is made on figure 3-37.

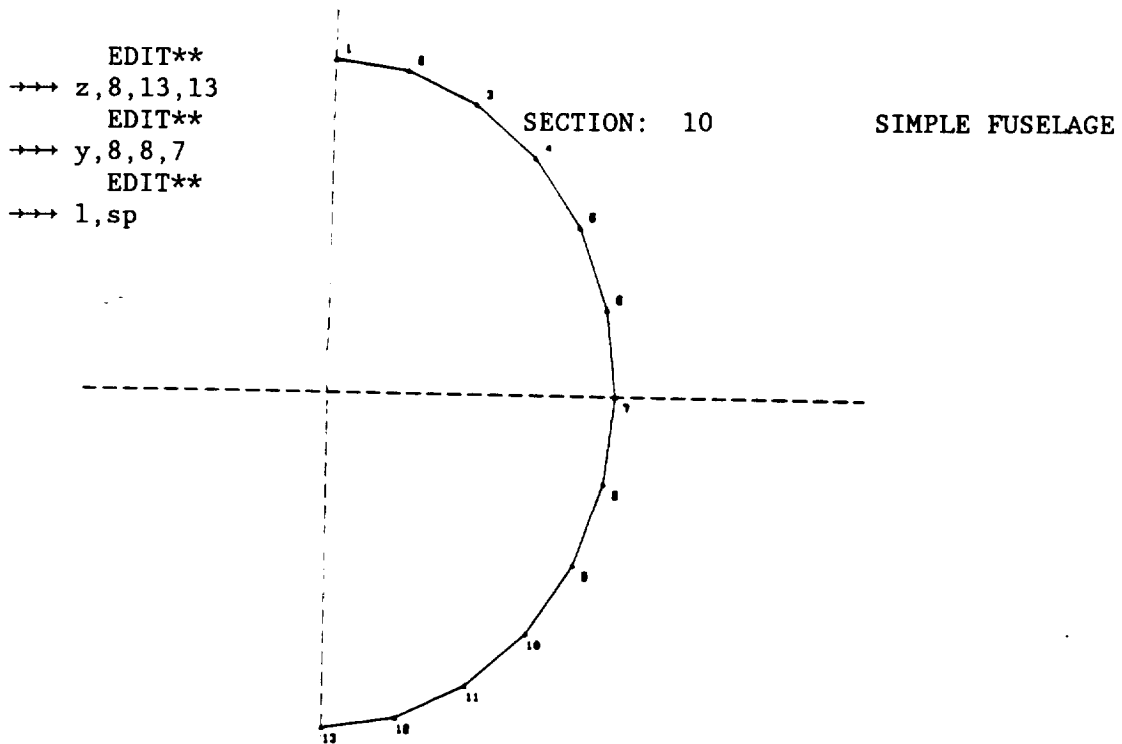


Figure 3-30. Modifying a Cross-section Using the Z and Y Subcommands of EDIT.

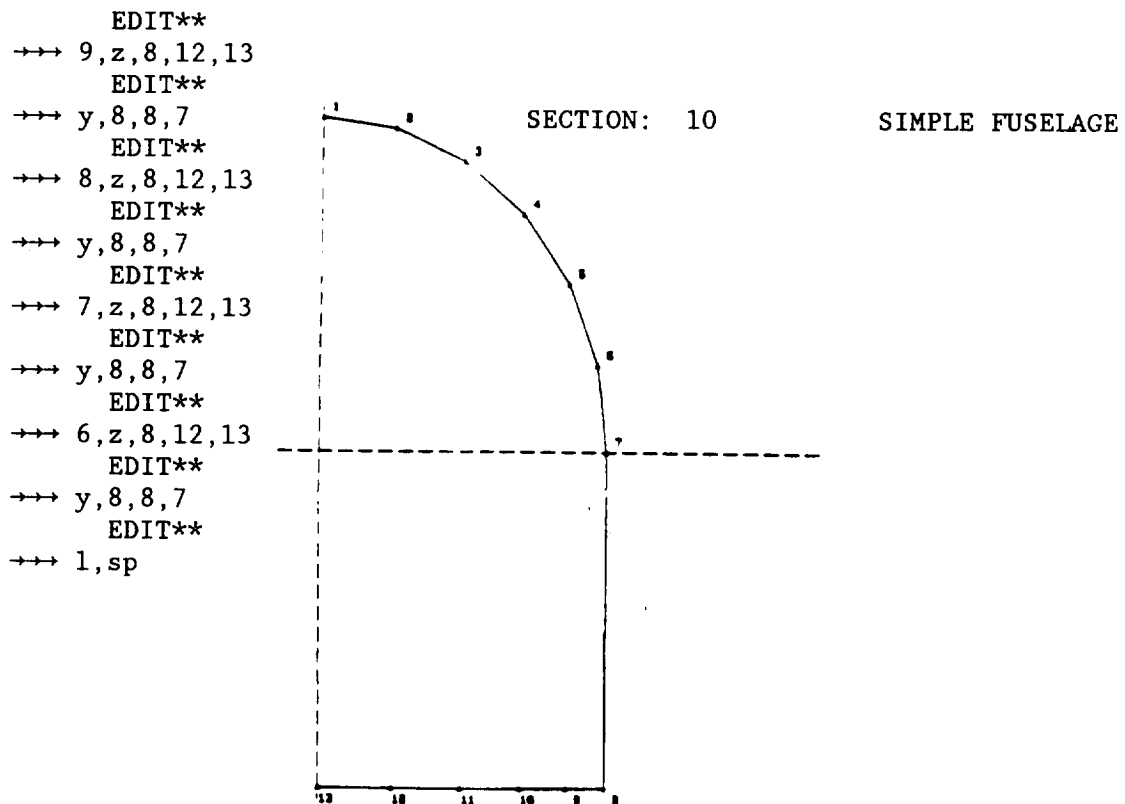


Figure 3-31. Modified Section from Figure 3-30 and Z and Y Changes to Sections 9,8,7,and 6.

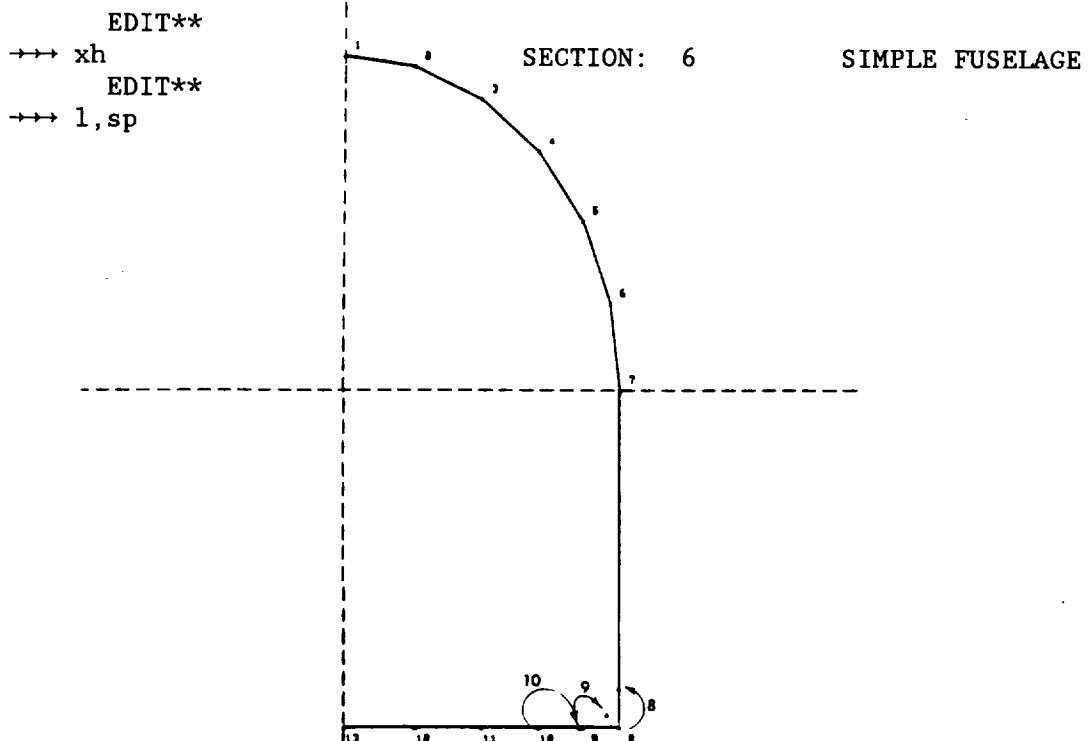


Figure 3-32. Rounding Off the Bottom of Section 6.

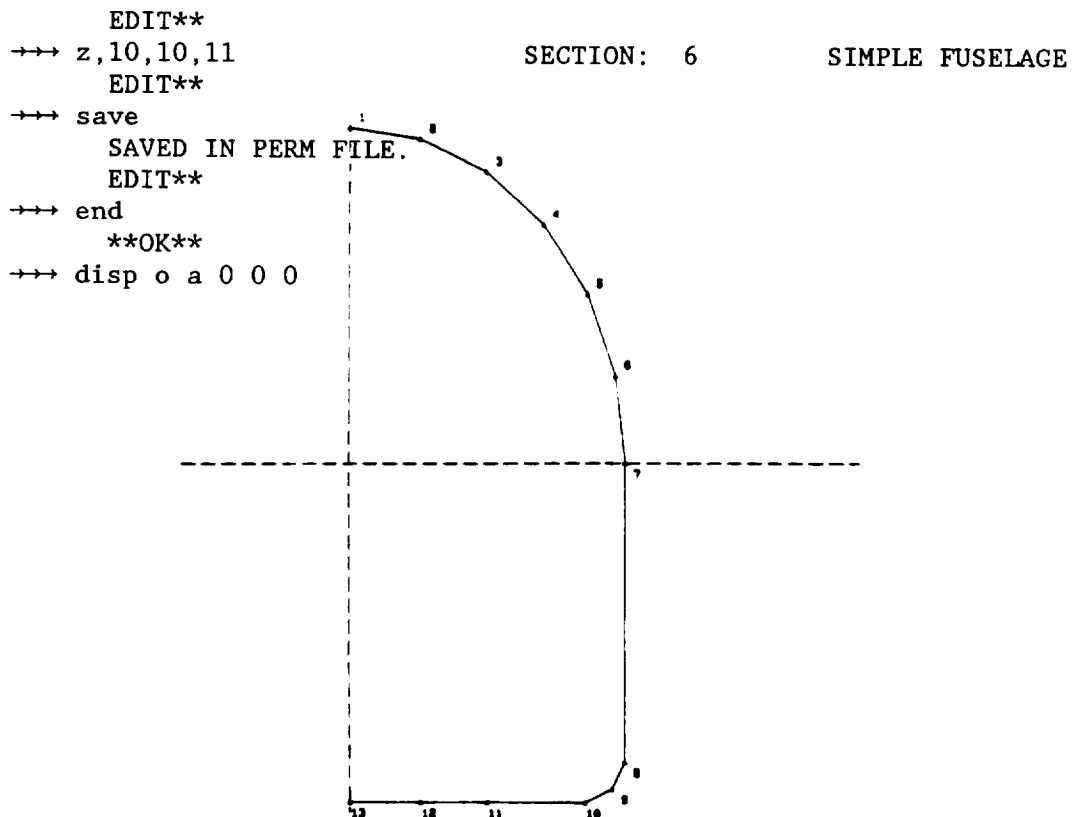


Figure 3-33. List of Section 6 Modifications and Saving the Fuselage.

APAS SAMPLE SESSION GEOMETRY FILE

YAW	PITCH	ROLL
0.0	0.0	0.0

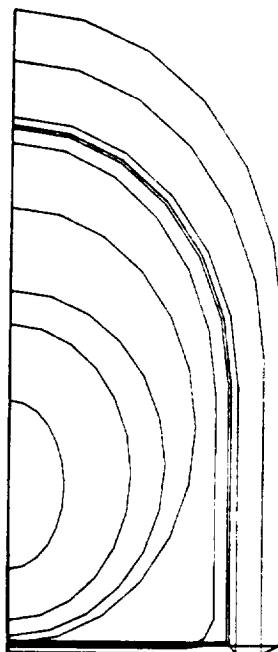


Figure 3-34. Front View of the Simple Fuselage.

APAS SAMPLE SESSION GEOMETRY FILE

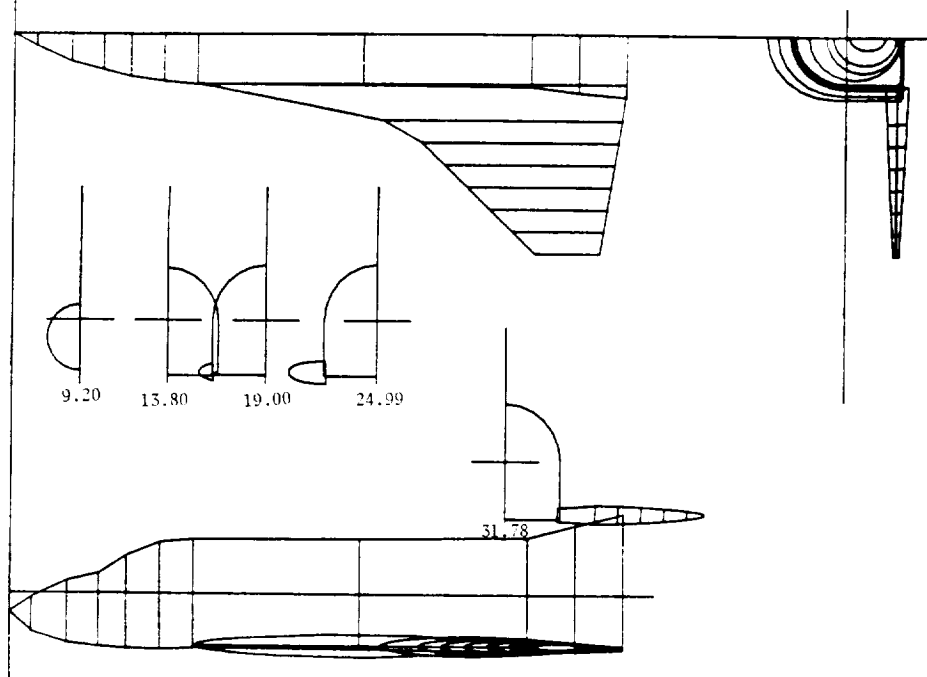


Figure 3-35. Three-view of Simple Wing and Fuselage Showing Improved Wing-body Interface.

```

EDIT**
--> parameter          SECTION: 1      SIMPLE WING
      101.00  SIMPLE WING
      TYPE: 4
      NWET:    1      1
      ENTER TYPE:
--> <CR>
      ENTER NWET VALUES:
--> <CR>
      COMPONENT SYMMETRY:      REFLECTIVE AND ASYMMETRIC
      ENTER:    1 : NON-REFLECTIVE
                2 :      REFLECTIVE
      POSITIVE :      ASYMMETRIC
      NEGATIVE :      SYMMETRIC
      CARRIAGE RETURN : UN-CHANGED
--> <CR>
      XO:  33.020 YO:    3.302 ZO:   -3.048
      ENTER NEW VALUES, PLACE COMMA TO LEAVE VALUE UNCHANGED:
--> ,,-2 362
      BET: 0.0 ALP: 0.0 GAM: 0.0
      ENTER NEW VALUES, PLACE COMMA TO LEAVE VALUE UNCHANGED:
--> <CR>

      VORTEX FORCES FOR THIS COMPONENT ARE OFF.
      ENTER "OFF" OR "ON" OR <CR> TO RETAIN:
--> <CR>
      EDIT**
--> save
      SAVED IN PERM FILE.
      EDIT**
--> end
      **OK**
--> disp all

```

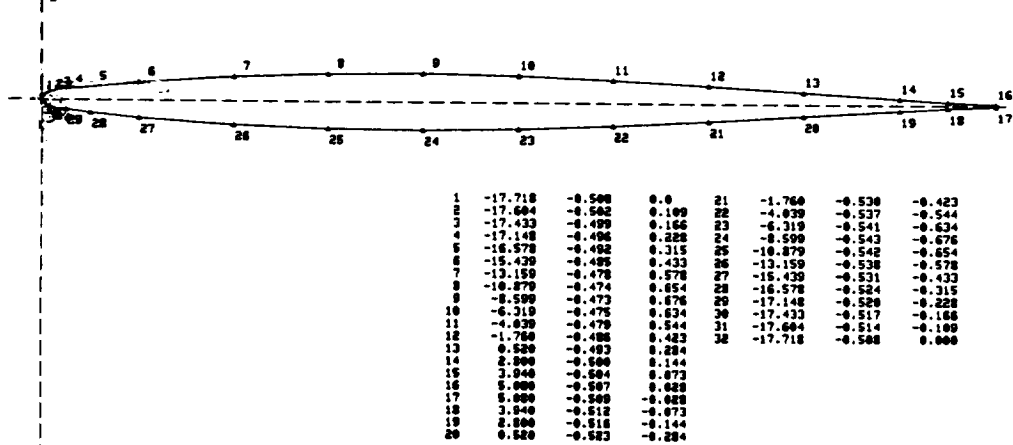


Figure 3-36. Using the Maximum Half Thickness of Wing Section 1 to Change ZO from -3.048 to -2.362.

APAS SAMPLE SESSION GEOMETRY FILE

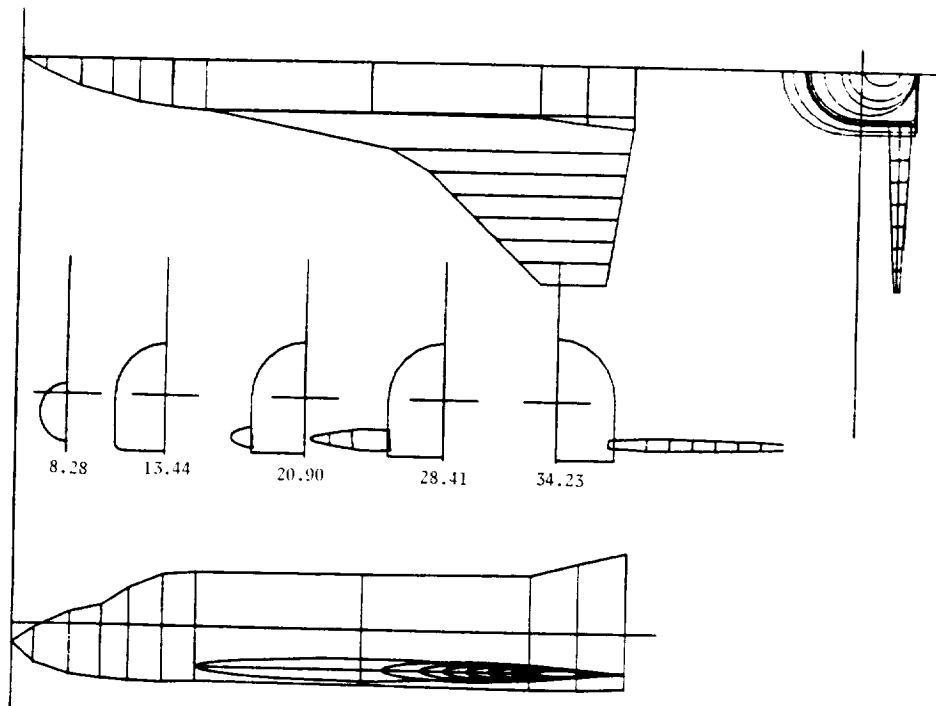


Figure 3-37. Three-view Showing Wing in its Final Position on the Fuselage.

Vertical Tail Input

Figure 3-38 illustrates the TERMINAL command input procedure for the vertical tail using data from table 4. The entries are similar to the wing. The work session continues on figure 3-39 using the VIEW subcommand of EDIT.

```
      **OK**
--> term
      * ENTER COMPONENT YAW,PITCH,ROLL :
--> <CR>
      0.0      0.0      0.0  DEFAULTS SELECTED

      * 1 FULL SURFACE
      * 2 HALF SURFACE
      * 3 FULL ELLIPSE
      * +4 HALF ELLIPSE UP      -4 HALF ELLIPSE DOWN
      * 5 RECTANGLE
      * +6 TRIANGLE UP          -6 TRIANGLE DOWN
      * E END
--> 2
      * INPUT COMPONENT NAME:
--> simple vertical
      * INPUT COMP NUMBER:
--> 201
      * HALF SURFACE
      XRO, YRO, ZRO (INBOARD LE)
--> 33.02 0 3.56
      * S,AR,TAPER,SWEEP(DEG),DIH(DEG):
--> 38.80 1.65 0.4 45 90
      * 1 65 A OXX
      * 2 64 A OXX
      * 3 SUPERCRITICAL
      * 4 HEX AIRFOIL
      * 5 BI-CONVEX
      * SELECT AIRFOIL TYPE:
--> 4
      *ENTER : (T/C)1 , (T/C)2 . . . (T/C)M, N <=10
      (DEFAULT VALUES: 0.05,0.05)
--> .03 .03
      **OK**
--> catalog
      **OK**
--> edit 201 10
      EDIT**
--> vi
```

Figure 3-38. Vertical Tail TERMINAL Input.

The W key is used to widen the tail-fuselage viewing space (figure 3-39) and the M key is used on figure 3-40 to move the vertical into position relative to the fuselage (steps 1 and 2). The view mode is ended (E, step 3), the vertical is saved, and a full configuration display is requested. The resulting three-view is shown on figure 3-41.

APAS SAMPLE SESSION GEOMETRY FILE

SIMPLE VERTICAL

YAW= 90.0 PITCH= -90.0 ROLL= -90.0

MENU OF KEY FUNCTIONS

(1) [W]

INSERT - 2ND ORDER : I
 INSERT - LINEAR : F
 DELETE : D
 SCALE TOP TO CURSOR : T
 " BOTTOM TO CURSOR : B
 MOVE UPPER TO CURSOR : U
 MOVE LOWER TO CURSOR : L
 TRANSLATE COMPONENT : M
 OVERWRITE : O
 REPAINT : R
 ZOOM - ENLARGE IMAGE : Z
 WIDE - SHRINK IMAGE : W
 END : E

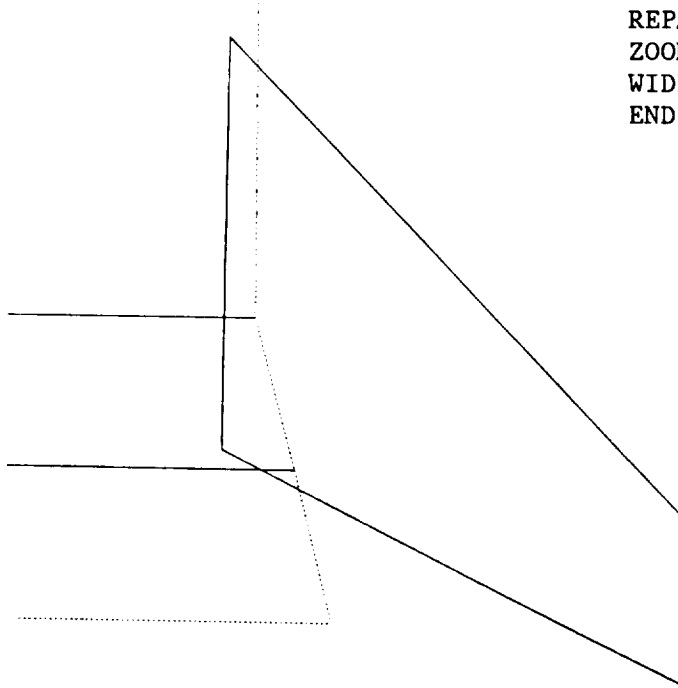


Figure 3-39. Viewing the Vertical and Widening the Viewing Space.

APAS SAMPLE SESSION GEOMETRY FILE

SIMPLE VERTICAL

YAW= 90.0 PITCH= -90.0 ROLL= -90.0

MENU OF KEY FUNCTIONS

EDIT**
 →→ save
 SAVED IN PERM FILE.
 EDIT**
 →→ end
 OK
 →→ disp all

INSERT - 2ND ORDER : I
 INSERT - LINEAR : F
 DELETE : D
 SCALE TOP TO CURSOR : T
 " BOTTOM TO CURSOR : B
 MOVE UPPER TO CURSOR : U
 MOVE LOWER TO CURSOR : L
 TRANSLATE COMPONENT : M
 OVERWRITE : O
 REPAINT : R
 ZOOM - ENLARGE IMAGE : Z
 WIDE - SHRINK IMAGE : W
 END : E

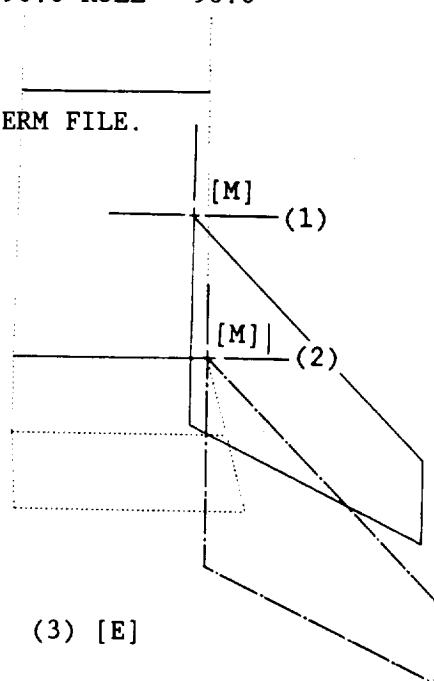


Figure 3-40. Vertical Tail Translation.

Development of the slender body and interference shell analysis components and wing, vertical and shell paneling will be deferred to the arbitrary configuration session to eliminate redundant discussion.

APAS SAMPLE SESSION GEOMETRY FILE

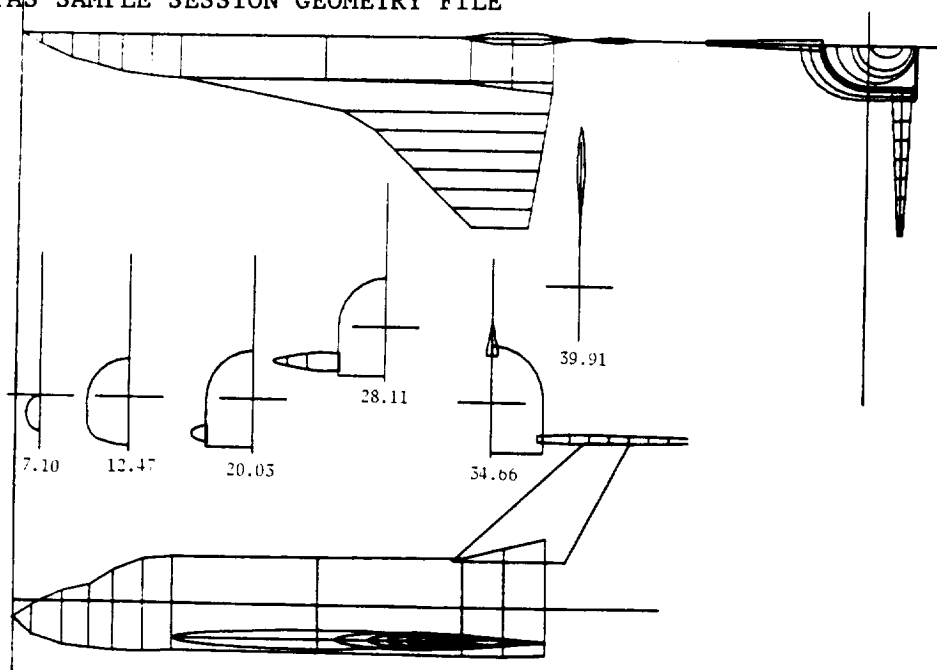


Figure 3-41. Configuration Three-view.

ARBITRARY CONFIGURATION (CASE #2/SESSION 3-2)

A drawing about one-fourth the size required for digitizing is presented on figure 3-42. Auxiliary contour data can be used if it is all to the same scale. A configuration input plan should be developed prior to logging on the system. This effort can markedly reduce input geometry session time and increase analysis flexibility on APAS.

The first planning step is to partition the configuration into body and surface components in order to properly apply the system aerodynamic analysis algorithms. These elements can be further partitioned as indicated on figure 3-43 to facilitate digitizing, aerodynamic buildup analysis, etc. Decisions concerning which of the configuration elements will be digitized using the DIGIT command, keyboard input using the TERMINAL command, or card input using the CARD command are made at this time. In the present case, it was elected to digitize the entire vehicle. Of course, if the user has access to APAS compatible digitized data as through the APASIN command or through an interface like GEOMOD or Rockwell's IDAS, then this session example can be bypassed. However, the process of planning the configuration input should be valuable in either case and is therefore recommended reading.

The fuselage is examined to locate canopy lines, contour corners, and wing, vertical tail, and pod attachment lines. This information is used to establish fuselage defining segments. To eliminate carrying a zero segment the length of the body for the wing and pods (figure 3-44), the fuselage is split into three components. Each is reviewed to establish segment definitions as indicated on figure 3-45. The use of double and triple points to preserve the same number of segments for a particular component is illustrated. For example, the point at which two segments meet is entered twice (double point).

The input process for the pod is similar to the fuselage and will not be repeated.

The wing is now examined. The planform is squared off at the root and tip to provide streamwise edges as indicated on figure 3-46. Chord lines are defined on the top view for the available section cuts. The leading edges of these chord lines are next located along the wing leading edge in the side view. Airfoils can be digitized using one, two or three segments. The first and last define the upper and lower surface respectively. The second segment (of a three segment definition) provides for a blunt trailing edge. A single segment surface can be used for "camber plane" linear analysis. Various default airfoil options are also provided.

The vertical tail leading and trailing edge points of the root and tip are transferred from the side view to the top view as indicated on figure 3-47. The root chord is digitized by entering the leading-edge point in the side view, moving up the transfer line to the centerline in the top view and entering a point and then moving along the centerline to the trailing edge point to complete the chord line definition. The process is repeated for the tip. Airfoils are defined in the same manner as for the wing.

The configuration is now ready for input to APAS.

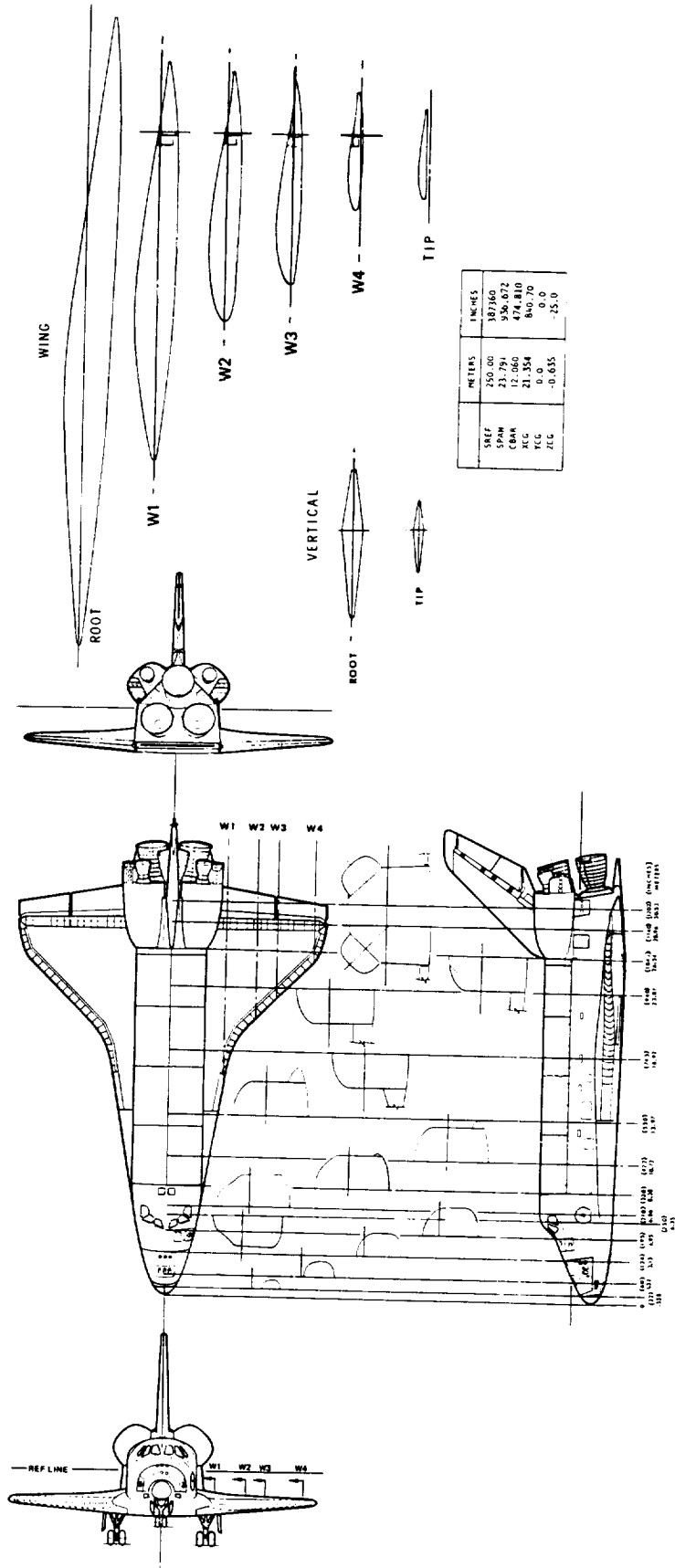


Figure 3-42. Space Shuttle Orbiter Three-view.

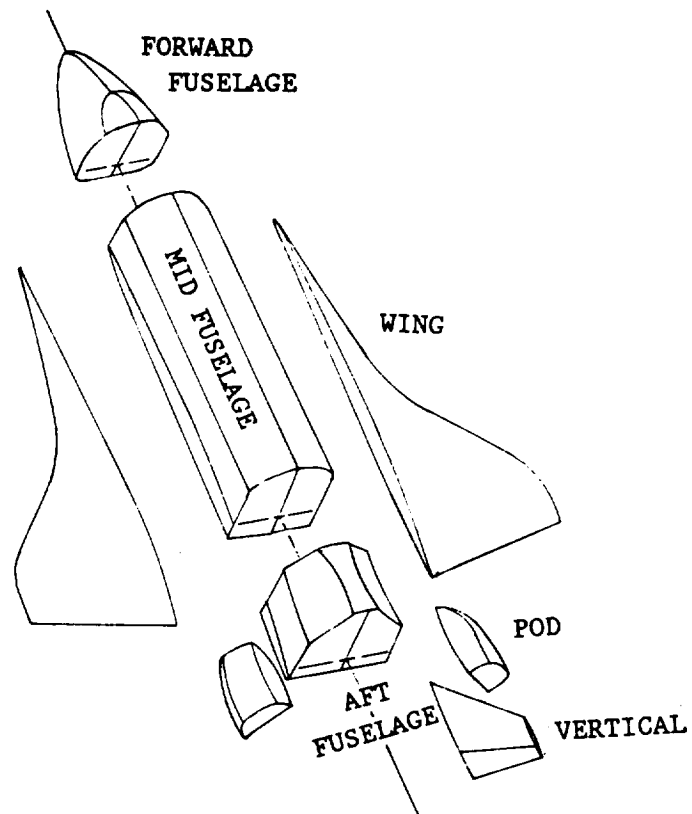


Figure 3-43. Space Shuttle Orbiter Components.

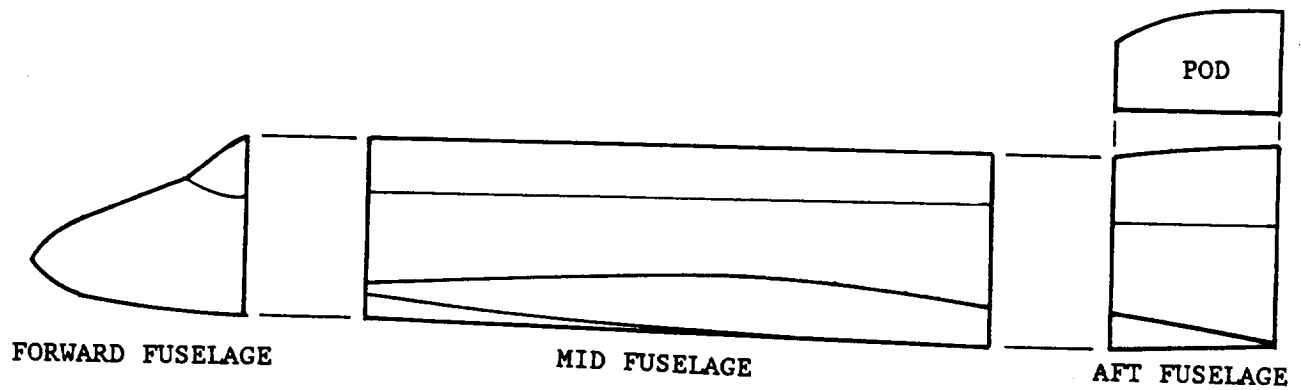


Figure 3-44. Fuselage Partitioning for Digitizing.

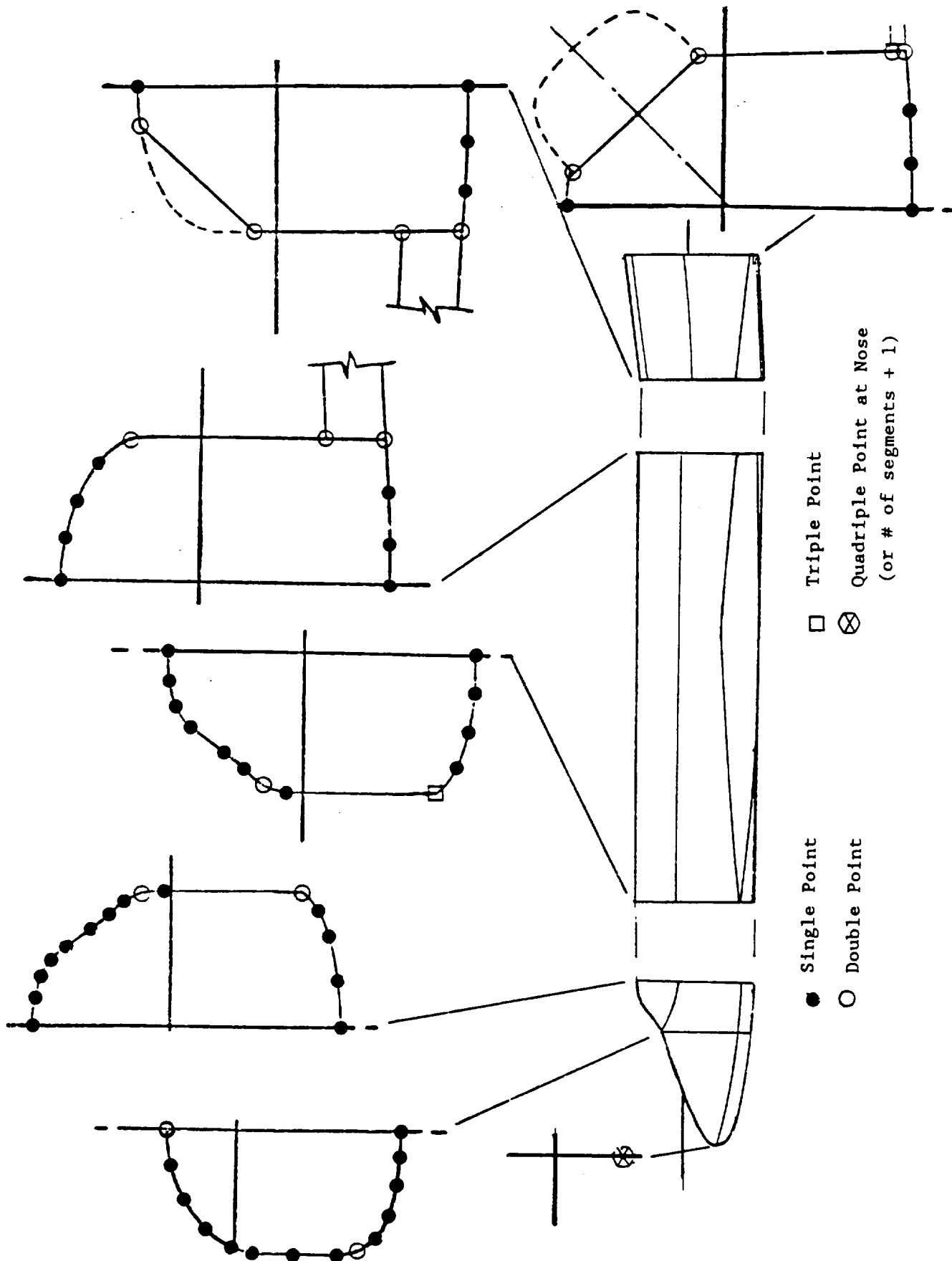


Figure 3-45. Examples of Digitizing Sections on Various Body Components.

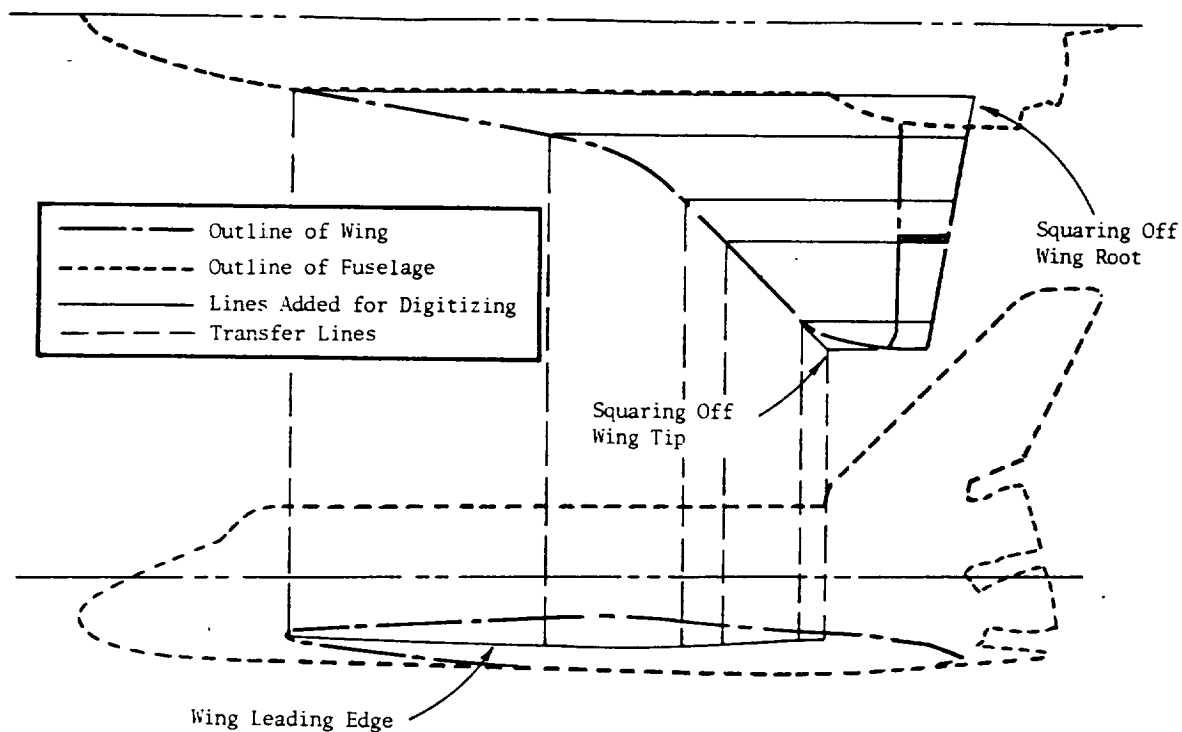


Figure 3-46. Previewing Wing Surface, Adding Guide Lines and Transfer Lines for Digitizing.

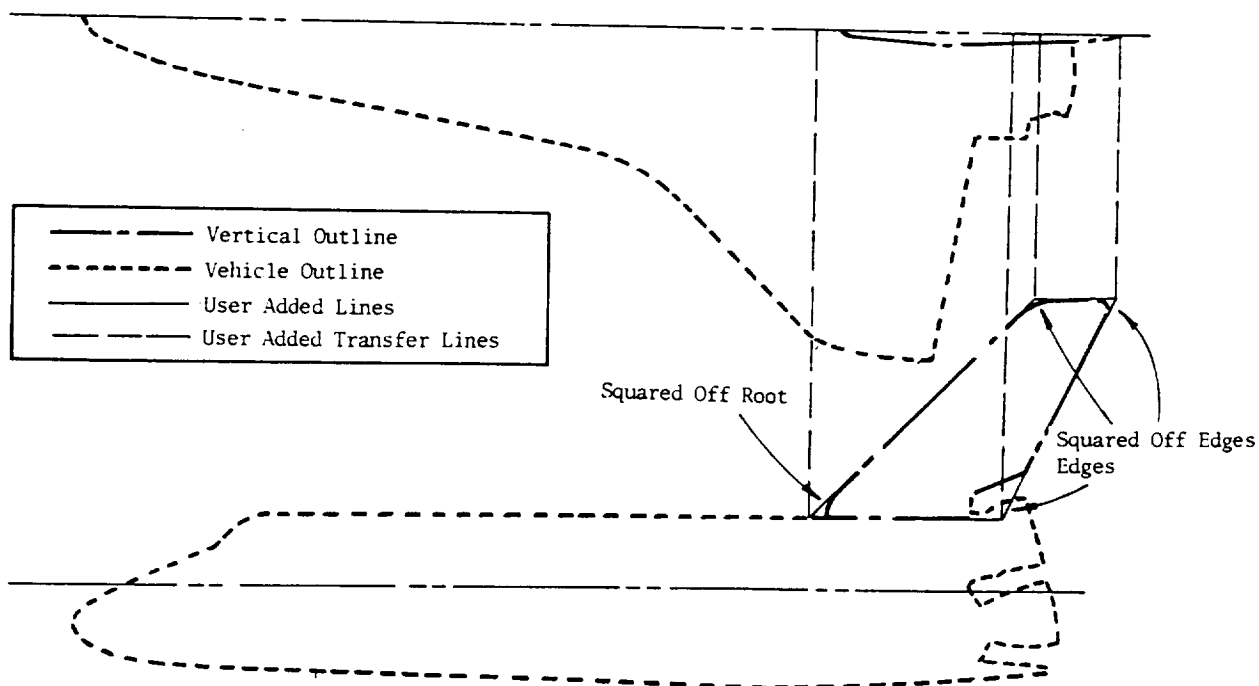


Figure 3-47. Previewing Vertical Tail, Adding Guide Lines and Transfer Lines for Digitizing.

Digitizing

The drawing of figure 3-42 is taped to the graphics tablet such that the areas being digitized sit on the active surface. Log into APAS using the same geometry file as the sample geometry case. Review the components in the permanent file using the FILES command.

Enter DIGITIZE and refer to figure 3-48 for the inputs to initiate digitizing. In this session, the forward fuselage and wing input will be defined. The first entry (X0, Xmax) is the x-station values of the selected origin and another point providing a reasonable distance for scaling the drawing. Xmax is usually taken as the largest x-station on the active tablet surface. The second entry is (X0,Y0) top screen to verify these entries, followed by the question "AXIS OK * YES * 2 NO." User should accept if the points are near orthogonal. The next entry is the basic component parameters: the type of component, the number of segments per cross-section, and the status of each segment; 1 for a wetted (exposed) and -1 for an unwetted. This is followed by the component number, name and symmetry. The forward fuselage, component 11.00, will be a type 1 body with three wetted segments.

```
*KEY * X0,XMAX *
--> 0 30.683
PEN * PLANFORM X0. PROFILE X0. PROFILE XMAX *

AXIS OK * 1 YES * NO
--> 1
COMPONENT PARAMETERS
KEY*TYPE(1,2,3 OR 4), NSEG, NWET(1)...NWET(NSEG)
--> 1 3 1 1 1

INPUT COMPONENT NUMBER:

--> 11

INPUT COMPONENT NAME:
--> forward fuselage

ENTER SYMMETRY PARAMETER:
1 : NON - REFLECTING
2 : REFLECTING
+ : ASYMMETRIC
- : SYMMETRIC
--> 2
```

(X0, Y0)

□

(X0,Z0)

□

(Xmax, Z0)

□

Figure 3-48. Forward Fuselage General Digitizing Input.

Figures 3-49 through 3-54 illustrate the steps for pen digitizing each of the forward fuselage sections. Symbols on each cross-section display have been added to show the contour points digitized. The x-return indicates the completion of the pen input and displays the section origin to allow modification if desired. In these screens the user changes the X0 value only. If it is desired to change Z0 only, then the input would be:,, and new Z0 value. The commas indicate no change to X0 and Y0. Two other options are available to signal the end of pen input. The s (save) return indicates pen input is complete and requests the data be saved. The r (repeat) return option is used to terminate pen input when the user has made a digitizing error and desires to start over. These latter two options have not been used in the present set of screens. Once X0 has been input through the keyboard the section data are printed in the upper right corner of the screen and a prompt message is printed in the lower left. The user enters a one (to signal desire to input yet another section) until end of component is achieved.

* SECTION: 1 NO. SEG.: 3, PTS/SEG.: 1 1 1
 XO = 0.0 YO = 0.0 ZO = -1.459

(1) PEN * FUSELAGE REF.
 * SEGMENTS FROM TOP OF SECTION

(2)→→→ x

INPUT XO,YO,ZO FOR SECTION, DEFAULTS:

(3)→→→ XO: -0.001 YO: 0.0 ZO: -1.459
 0.

* 1 NEXT SECTION * 2 REPEAT SECTION * 3 END COMP.

(4)→→→ 1

Figure 3-49. Digitizing Forward Fuselage Section 1.

* SECTION: 2 NO. SEG.: 3, PTS/SEG.: 1 5 3
 XO = 0.559 YO = 0.0 ZO = -0.754

(1) PEN * FUSELAGE REF.
 * SEGMENTS FROM TOP OF SECTION

(2)→→→ x

INPUT XO,YO,ZO FOR SECTION, DEFAULTS:

(3)→→→ XO: 0.559 YO: 0.0 ZO: -0.754
 0.559

* 1 NEXT SECTION * 2 REPEAT SECTION * 3 END COMP.

(4)→→→ 1

Figure 3-50. Digitizing Forward Fuselage Section 2.

* SECTION: 3 NO. SEG.: 3, PTS/SEG.: 1 7 4
 XO = 1.524 YO = 0.0 ZO = -0.201

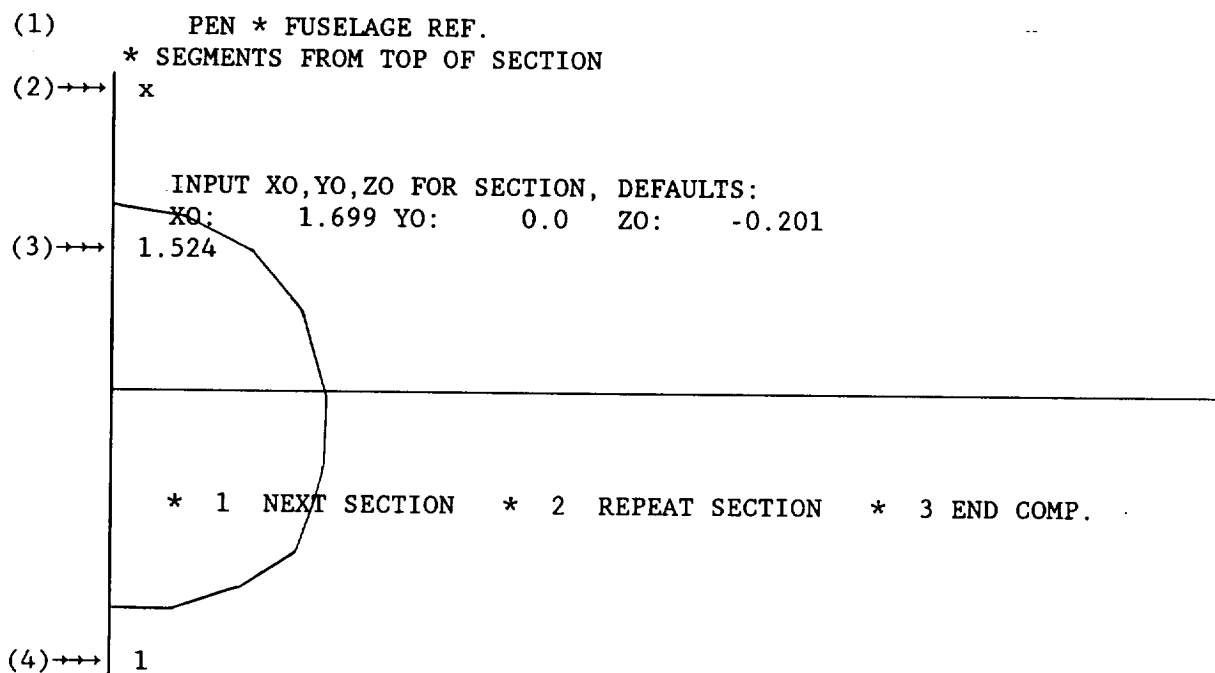


Figure 3-51. Digitizing Forward Fuselage Section 3.

* SECTION: 5 NO. SEG.: 3, PTS/SEG.: 1 9 5
 XO = 4.953 YO = 0.0 ZO = 1.207

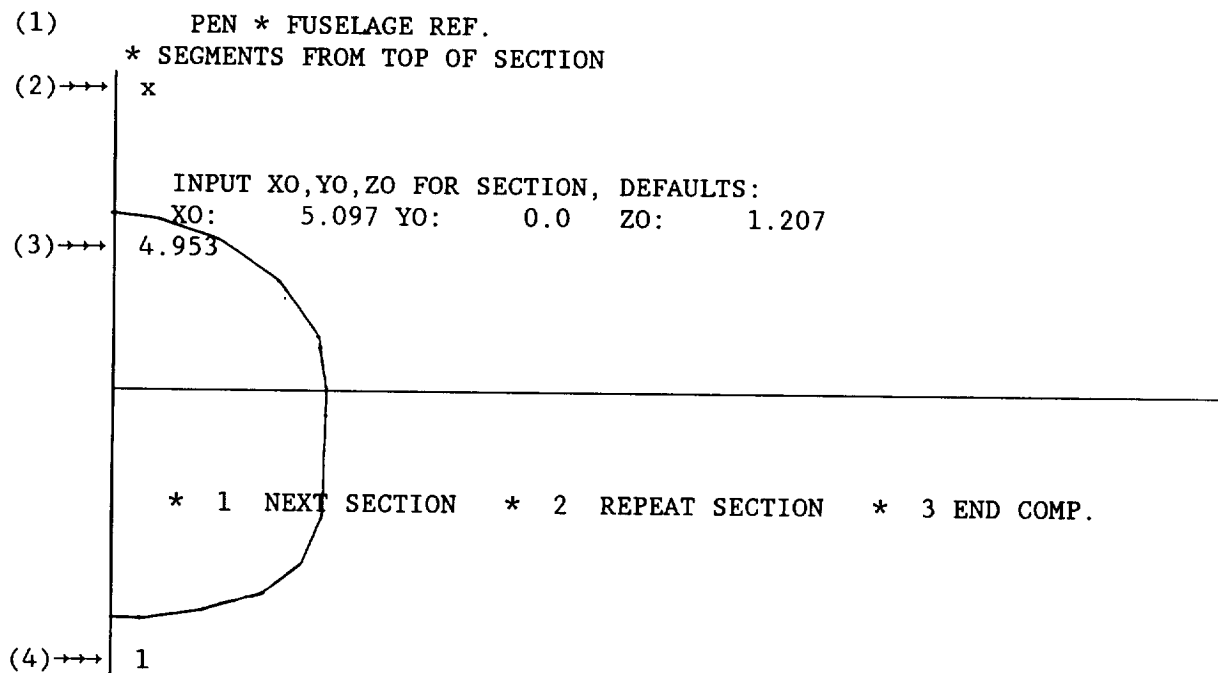


Figure 3-52. Digitizing Forward Fuselage Section 5.

* SECTION: 6 NO. SEG.: 3, PTS/SEG.: 7 3 5
 XO = 6.324 YO = 0.0 ZO = 2.263

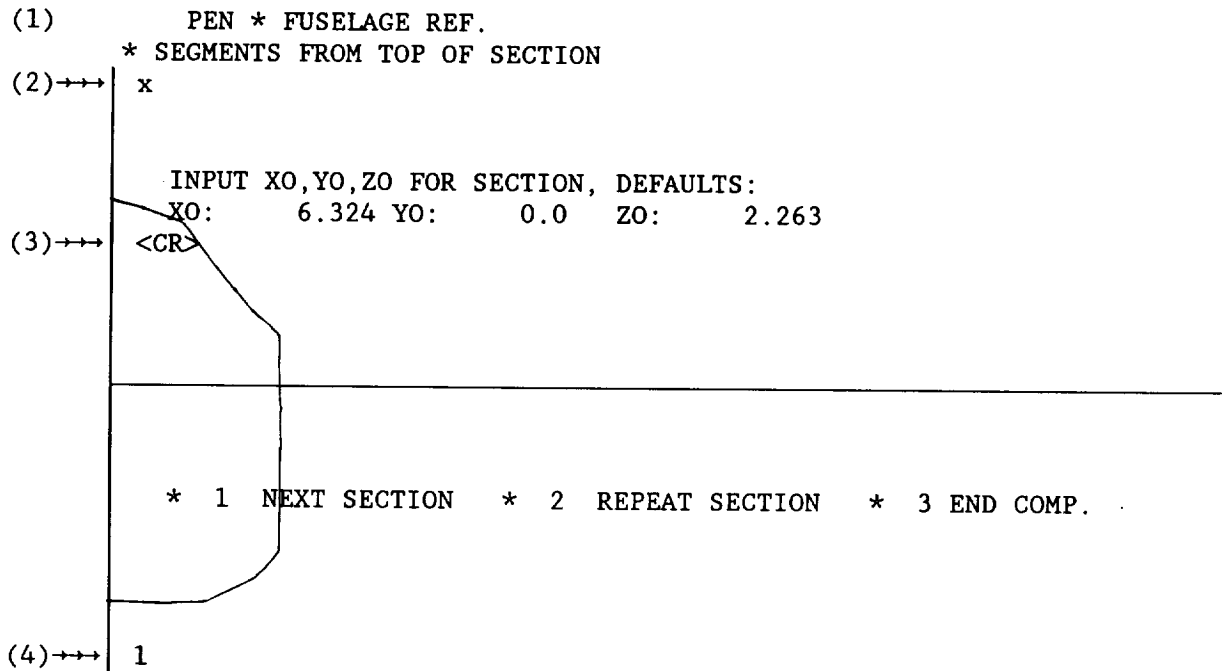


Figure 3-53. Digitizing Forward Fuselage Section 6.

* SECTION: 7 NO. SEG.: 3, PTS/SEG.: 7 5 5
 XO = 6.858 YO = 0.0 ZO = 2.465

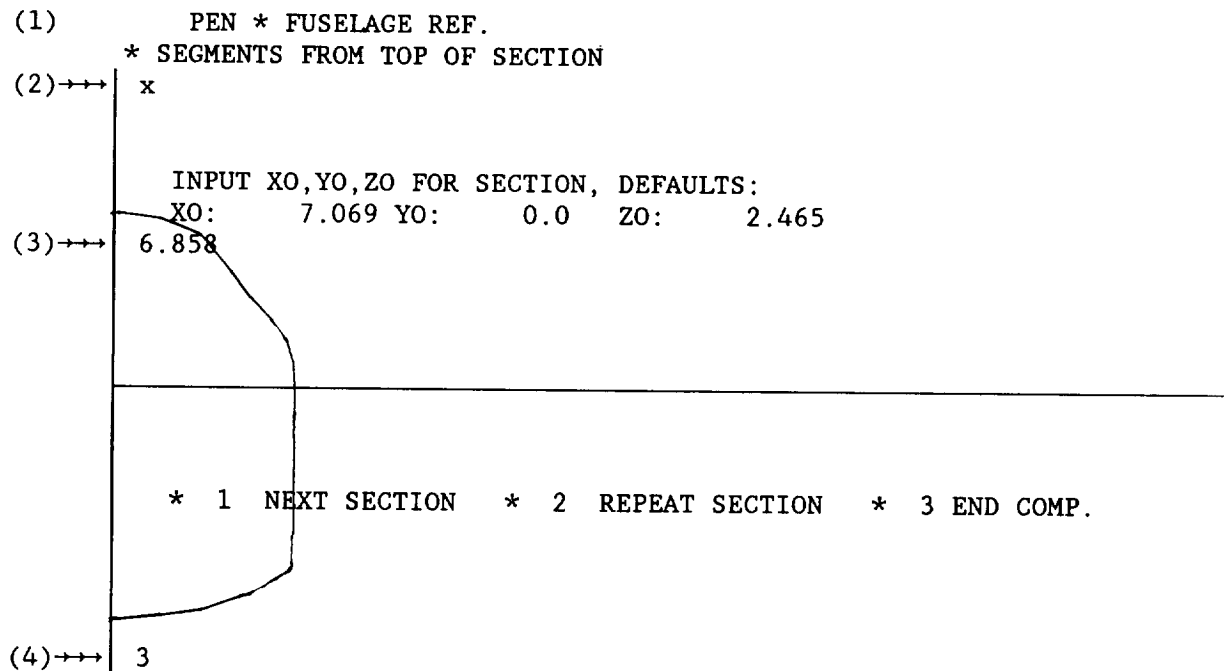


Figure 3-54. Digitizing Forward Fuselage Section 7 and Ending Component Digitizing.

Figure 3-55 illustrates the entries for processing and storing the geometry. The smoothing option will be illustrated for wing digitizing where irregularities in geometry are more important. The user is also given the opportunity to change the number of segment points by interpolation (bodies only). In the present case, the default values are accepted and represent the maximum number of points used for each segment as determined from all 7 input sections. An EDIT/LIST of each section will display a total of 21 points with the number of points in each segment as shown. The component is cataloged and a three-view is displayed on figure 3-56.

```

*SMOOTH OPTION:  ENTER ORDER OF
*CARRIAGE RETURN FOR SPLINE FIT ONLY.
+>>> <CR>
      POINTS/SEGMENT ENRICHMENT
      ENTER NEW VALUES OR CARRIAGE RETURN TO RETAIN.
      PRESENT VALUES:    7    9    5
+>>> <CR>
      **OK**
+>>> cata
      **OK**
+>>> disp

```

Figure 3-55. Body Contour Processing.

APAS SAMPLE SESSION GEOMETRY FILE

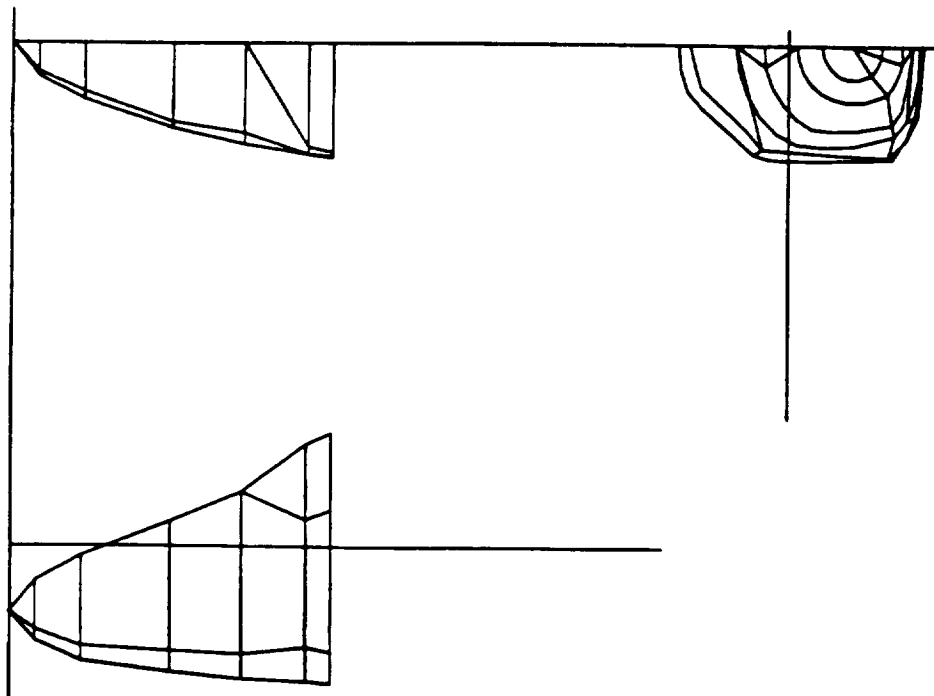


Figure 3-56. Three-view of Digitized Forward Fuselage.

The mid and aft fuselage and pod are input similarly. The initial data for these components is shown in figures 3-57, 3-58, 3-59 respectively. Since the pod is a type 2 component the cross sections are digitized to closure as indicated on figure 3-60.

```

      *KEY * XO,XMAX
--> 0 30.531
      PEN * PLANFORM XO, PROFILE XO, PROFILE XMAX *

      AXIS OK * 1 YES * 2 NO
--> 1
      COMPONENT PARAMETERS
      KEY*TYPE(1,2,3, OR 4),NSEG, NWET(1).....NWET(NSEG)
--> 1 4 1 1 -1 1
      INPUT COMP NUMBER:
--> 12
      INPUT COMPONENT NAME:
--> mid fuselage
      ENTER SYMMETRY PARAMETER:
      1 : NON - REFLECTING
      2 : REFLECTING
      + : ASYMMETRIC
      - : SYMMETRIC
--> 2

```

Figure 3-57. Mid Fuselage General Digitizing Input.

```

      *KEY * XO,XMAX
--> 0 30.531
      PEN * PLANFORM XO, PROFILE XO, PROFILE XMAX *

      AXIS OK * 1 YES * 2 NO
--> 1
      COMPONENT PARAMETERS
      KEY*TYPE(1,2,3, OR 4),NSEG, NWET(1).....NWET(NSEG)
--> 1 5 1 -1 1 -1 1
      INPUT COMP NUMBER:
--> 13
      INPUT COMPONENT NAME:
--> aft fuselage
      ENTER SYMMETRY PARAMETER:
      1 : NOW - REFLECTING
      2 : REFLECTING
      + : ASYMMETRIC
      - : SYMMETRIC
--> 2

```

Figure 3-58. Aft Fuselage General Digitizing Input.

```

*KEY * XO,XMAX
--> 0 30.531
    PEN * PLANFORM XO, PROFILE XO, PROFILE XMAX *

    AXIS OK * 1 YES * 2 NO
--> 1
    COMPONENT PARAMETERS
    KEY*TYPE(1,2,3, OR 4),NSEG, NWET(1).....NWET(NSEG)
--> 2 2 1 -1
    INPUT COMP NUMBER:
--> 14
    INPUT COMPONENT NAME:
--> pod
    ENTER SYMMETRY PARAMETER:
    1 : NON - REFLECTING
    2 : REFLECTING
    + : ASYMMETRIC
    - : SYMMETRIC
--> 2

```

Figure 3-59. Pod General Digitizing Input.

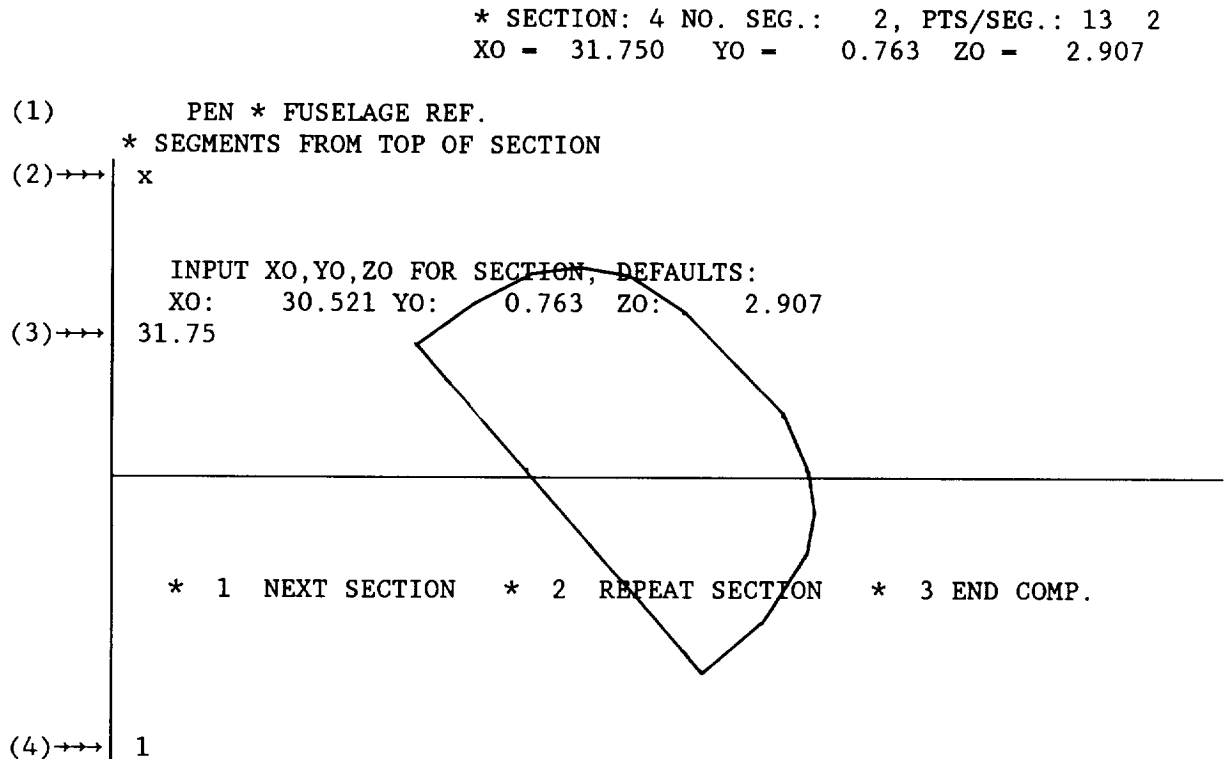


Figure 3-60. Digitized Pod Contour.

When the four components have been digitized, a three view of the complete fuselage is produced (figure 3-61) using the DISPLAY command.

APAS SAMPLE SESSION GEOMETRY FILE

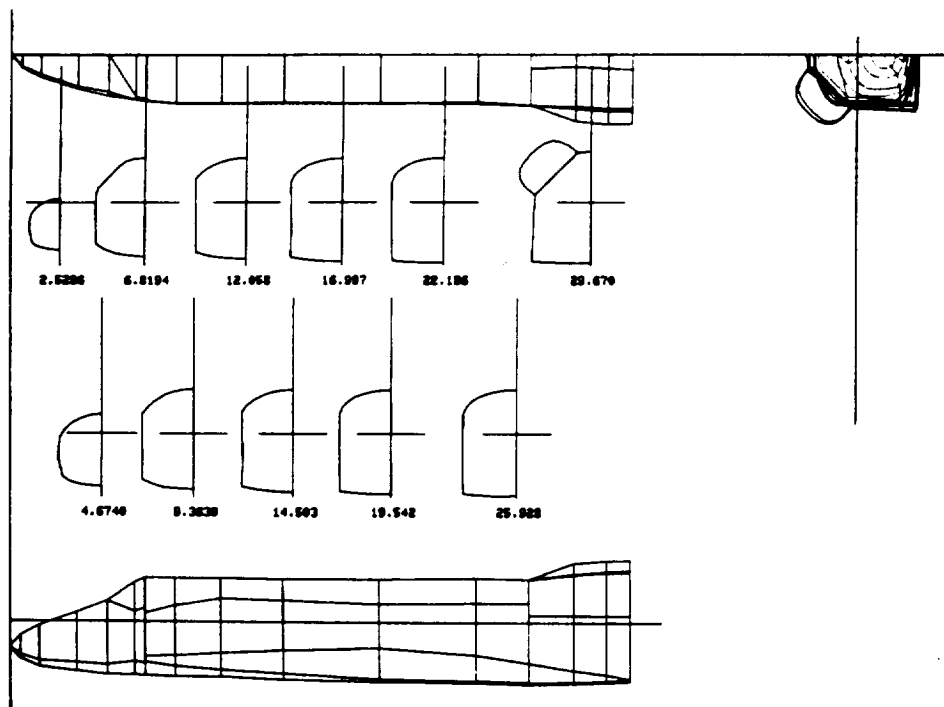


Figure 3-61. Fuselage Three-view.

The general input for the wing (type 4) is shown on figure 3-62. The indicated key and pen input are required to establish scale and location data. Screens of the digitized sections are shown on figures 3-63 through 3-65 for airfoils 1,2 and the tip. Note the negative thickness input to indicate section digitizing, the chord line location points (rectangles on figure) and the section definition. After defining the origin and chord, the user can now pen in the airfoil cross-section. A s (save) return terminates digitizing and causes the section data to be printed at upper right. APAS then prompts the user on how to proceed as shown in the last line. In figure 3-64 the user indicated input is complete by keying in a s return. However, the number of segments input was wrong. APAS prints out the nature of the error, i.e., number of segments input is incorrect (3 is correct number) and requests user to re-enter pen input. The user does this and enters s a second time. APAS indicates acceptance by printing out the section data at upper right and then the prompt message shown below the airfoil section.

```

      *KEY * XO,XMAX
--> 0 30.531
      PEN * PLANFORM XO, PROFILE XO, PROFILE XMAX *

      AXIS OK * 1 YES * 2 NO
--> 1
      COMPONENT PARAMETERS
      KEY*TYPE(1,2,3, OR 4),NSEG, NWET(1).....NWET(NSEG)
--> 4 3 1 1 1
      INPUT COMP NUMBER:
--> 111                                (XO,ZO)   ☐
      INPUT COMPONENT NAME:
--> wing
      ENTER SYMMETRY PARAMETER:
      1 : NON - REFLECTING              (XO, ZO) ☐           ☐ (Xmax, ZO)
      2 : REFLECTING
      + : ASYMMETRIC
      - : SYMMETRIC
--> 2

```

Figure 3-62. General Input for Wing Digitizing.

* SECTION: 1 NO. SEG.: 3, PTS/SEG.: 10 2 5
 XO = 6.922 YO = 2.674 ZO = -2.233

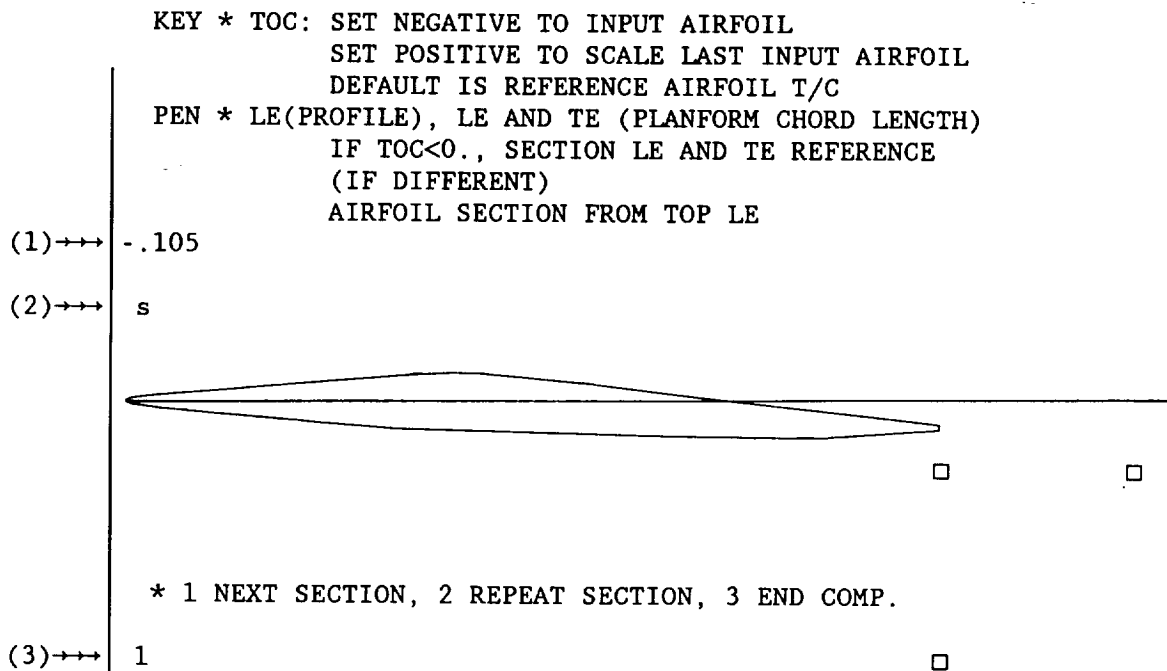


Figure 3-63. Digitizing Wing Section 1.

* SECTION: 2 NO. SEG.: 3, PTS/SEG.: 9 2 8
 XO = 16.756 YO = 4.092 ZO = -2.489

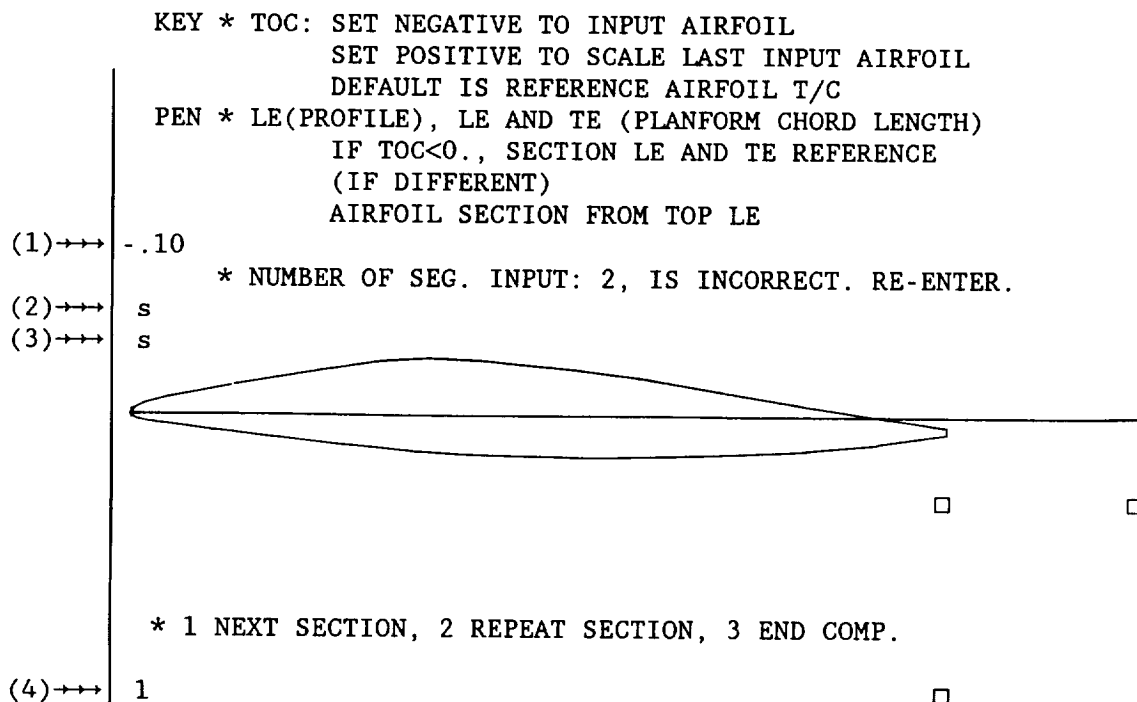


Figure 3-64. Digitizing Wing Section 2.

* SECTION: 5 NO. SEG.: 3, PTS/SEG.: 5 2 5
 XO = 26.795 YO = 11.585 ZO = -2.121

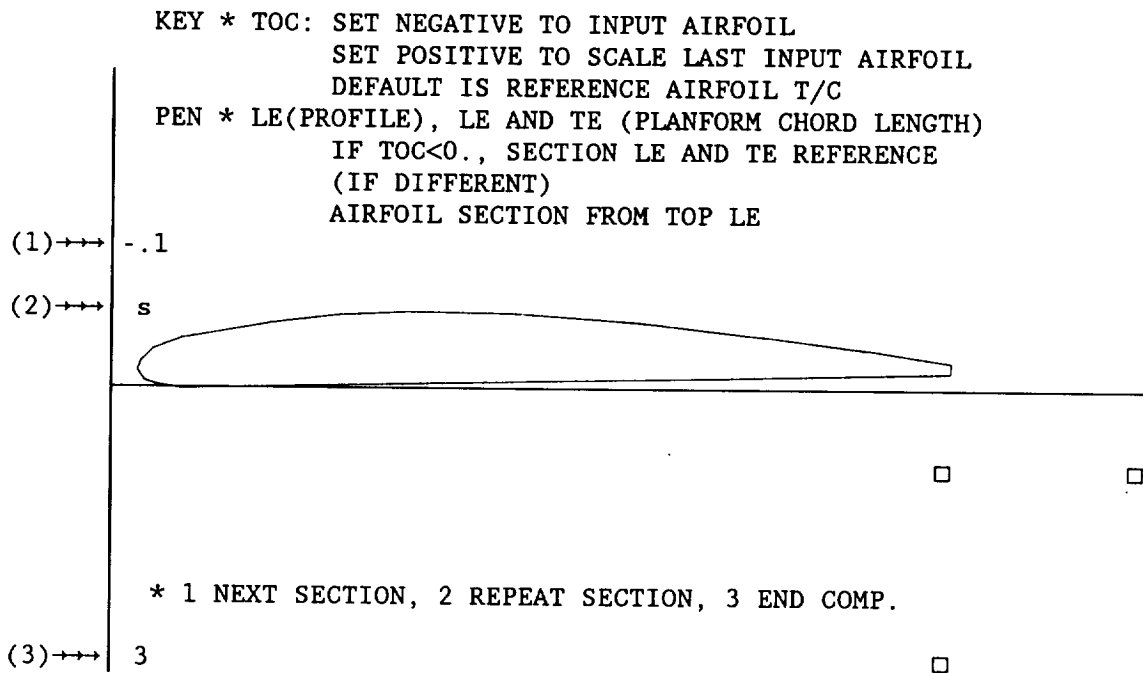


Figure 3-65. Digitizing Tip and Ending the Wing Input.

Digitized wing sections may be refined using polynomial smoothing in conjunction with a leading edge algorithm. Three options are available; a default sharp edge, a radius based on the detailed section, or NACA four and five DIGIT airfoil values given by $r/c = 1.10919 (t/c)^2$. The second option was selected here and input in response to prompts of the smoothing function. Screens 3-45 through 3-47 illustrate the resulting airfoil modifications. The vertical scale for these displays has been expanded by a factor of 2.5 for clarity. Each segment of greater than $n+1$ points (n being the order of the smoothing polynomial) is displayed and the user selects or rejects the refinement. In screen 3-45 for example, the smoothing was rejected in favor of the spline default definition.

The component is then cataloged. Due to the small drawing used, some planform editing may be required.

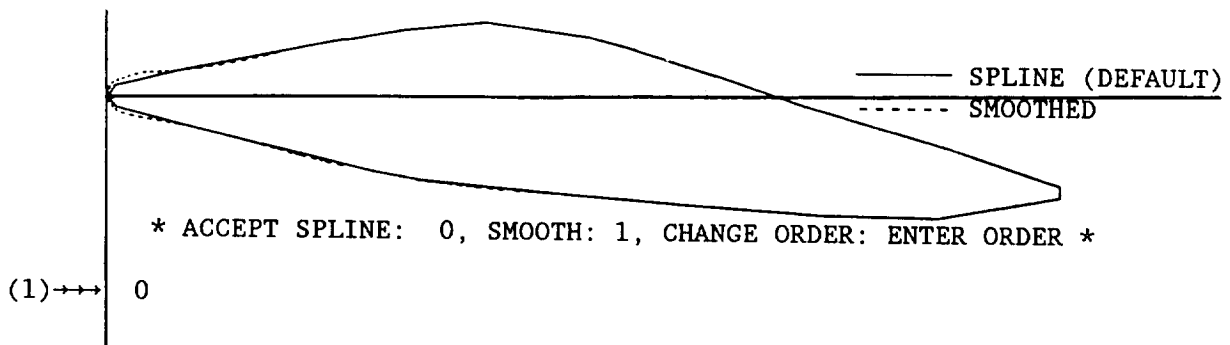


Figure 3-66. Processing Wing Section 1.

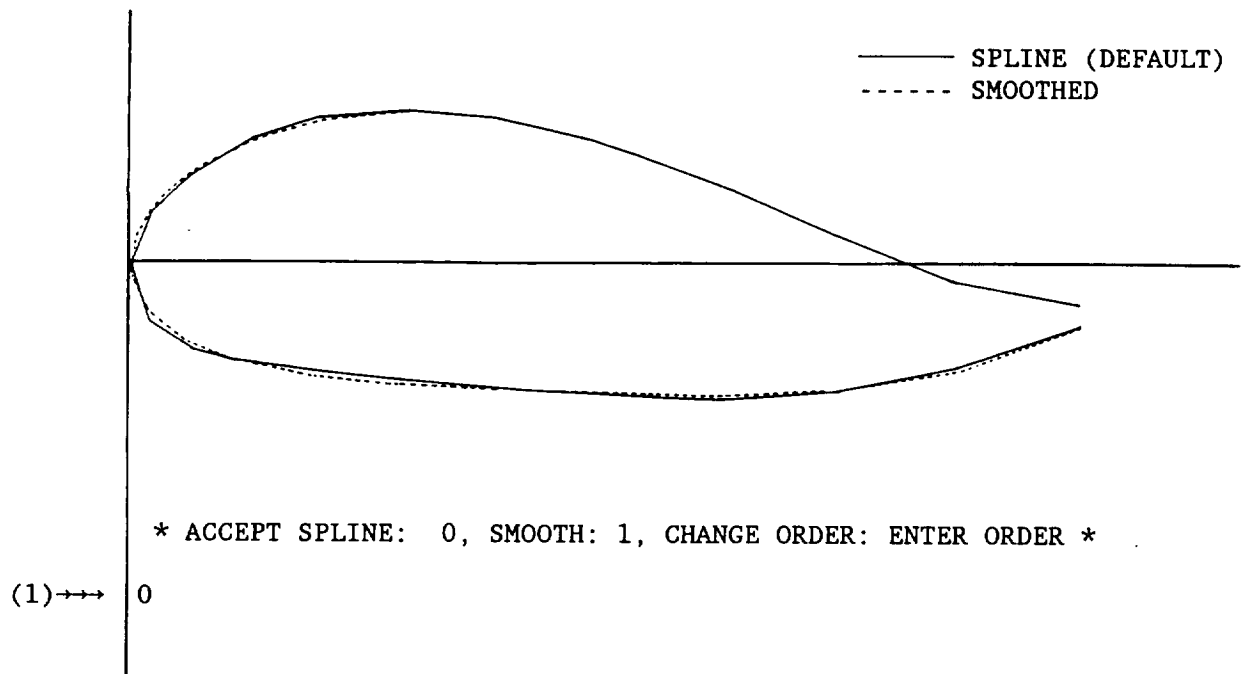


Figure 3-67. Processing Wing Section 2.

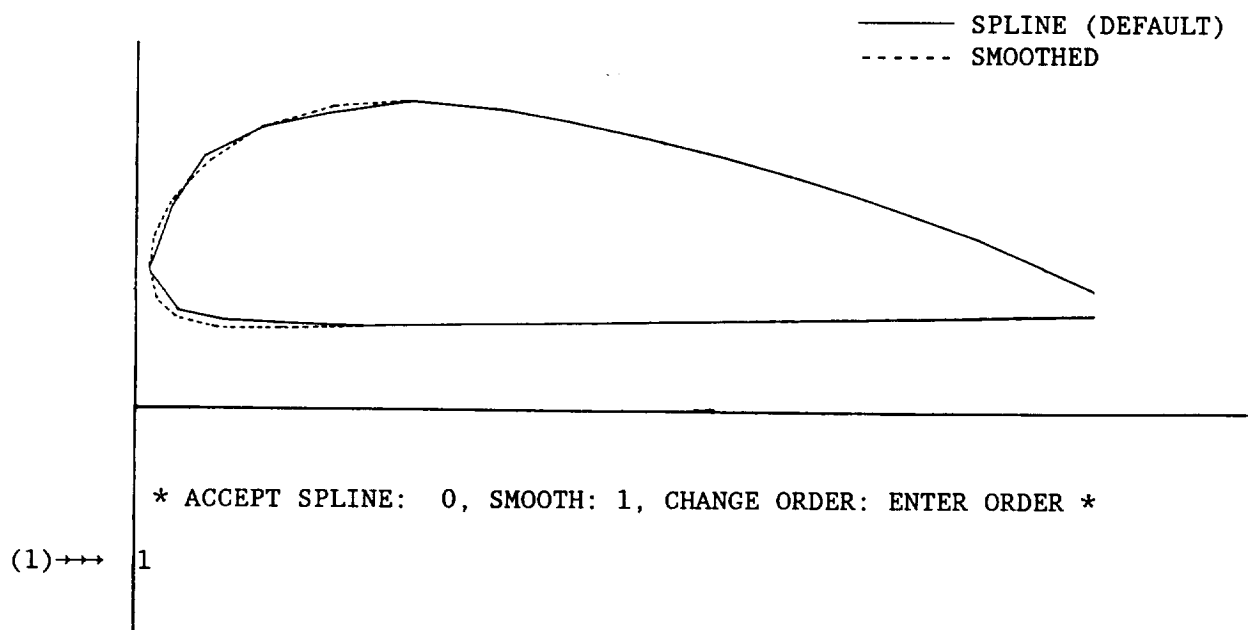


Figure 3-68. Processing Wing Tip.

The vertical tail is digitized using figure 3-42. The input procedure is similar to the wing and will not be shown.

A three-view display of the final configuration is presented on figure 3-69 and completes the input of the geometric components. The aerodynamic analysis requires that slender body and an interference shell components be developed and the wing, vertical tail and shell paneling defined using the PANEL subcommand of EDIT.

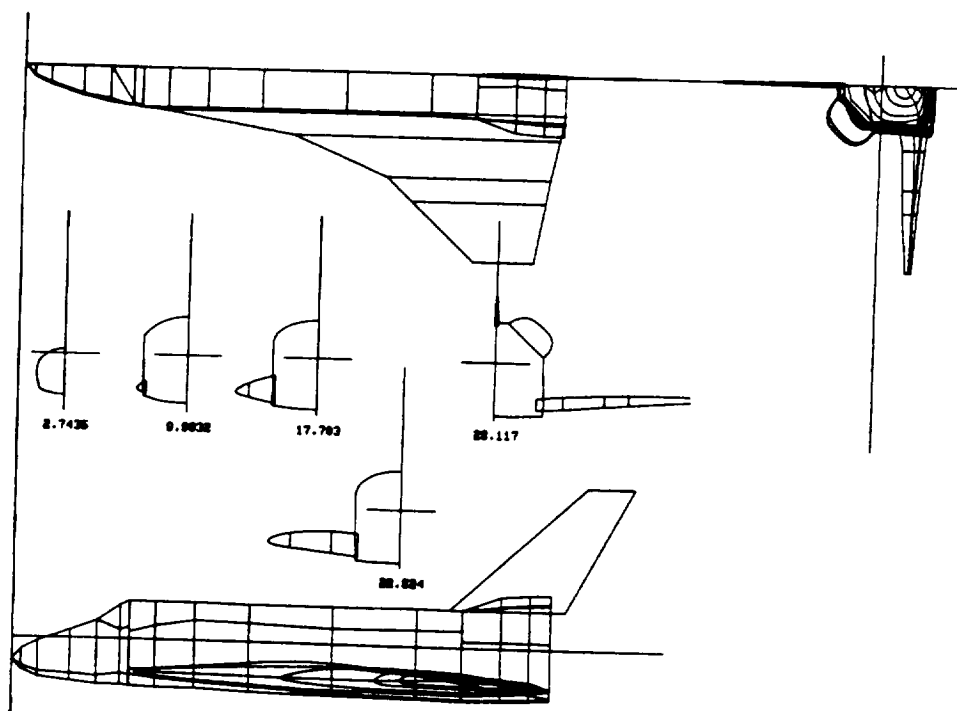


Figure 3-69. Complete Configuration Three-view.

Analysis Components

Subsonic-supersonic aerodynamic evaluation requires development of a slender body and interference shell pair for each body. In the sample configuration the fuselage of figure 3-61 is simulated by a slender body. The associated interference shell is constructed to approximate wing-body and tail-body intersections and must be assigned a component number within the same decade of the slender body component number.

Slender Body

A list of the components in the permanent file is displayed on figure 3-70. The user selects components 11 through 14 for slender body generation.

```
      **OK**
--> files
      COMPN          NAME          TYPE          SYMM
      10.00      SIMPLE FUSELAGE          1          2
      11.00      FORWARD FUSELAGE          1          2
      12.00      MID FUSELAGE          1          2
      13.00      AFT FUSELAGE          1          2
      14.00      POD          2          2
      101.00     SIMPLE WING          4          2
      111.00     WING          4          2
      121.00     WING          4          2
      201.00     SIMPLE VERTICAL          3          1
      211.00     VERTICAL          3          1
      **OK**
--> slender 11 12 13 14
```

Figure 3-70. Selecting Body Components for Generating the Slender Body.

In the sample shown in figure 3-71, a fuselage and nacelle are linked to form one component. At each point along the fuselage contour (starting at the top centerline) a check is made to determine if there are any contour points from other components located in the vicinity. The radius for this check is determined by the parameter FACTOR which is the fraction of the segment length to the next point on the fuselage contour. At point 6 on the fuselage, the first point of the nacelle contour falls within the radius (.7R) and thus the revised contour transitions to the nacelle. To prevent premature returning to the fuselage, additional nacelle contour points must be skipped before initiating the checking process. The number of points skipped is determined by NPASS. At point 10 of the nacelle, the revised contour transitions back to the fuselage to complete the linking. Figure 3-72 shows the commands that generate the slender body, catalogue and display it (as shown in figure 3-73) to verify that the contours are correct.

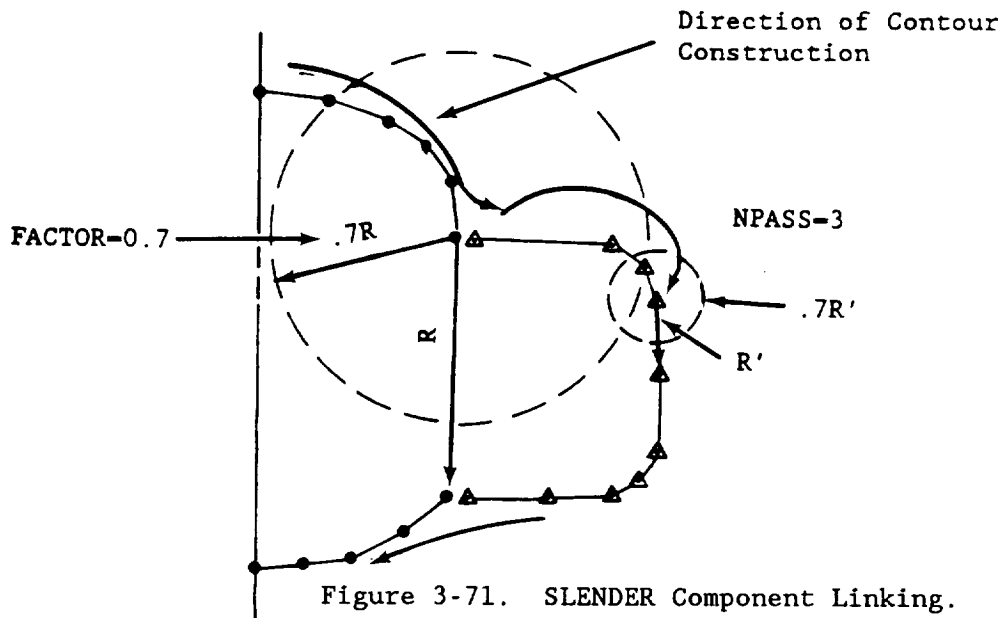


Figure 3-71. SLENDER Component Linking.

```

* SLENDER BODY SIMULATION *
* ENTER COMPONENT NAME *
--> slender body
* INPUT COMP NUMBER *
611
* COMPONENT PARAMETERS FOR SLENDER BODY COMBINATION *
* ENTER FACTOR NPASS (DEFAULTS: 0.7,3) *
--> <CR>
**OK**
--> catclog
INVALID COMMAND CATCLOG
RE-ENTER INPUT
--> catalog
**OK**
--> disp 611 o a 60-30 30

```

Figure 3-72. Entries Required to Generate a Slender Body from Several Fuselage Components.

APAS SAMPLE SESSION GEOMETRY FILE

```

YAW  PITCH  ROLL
60.0  -30.0  30.0

```

(1) [E]

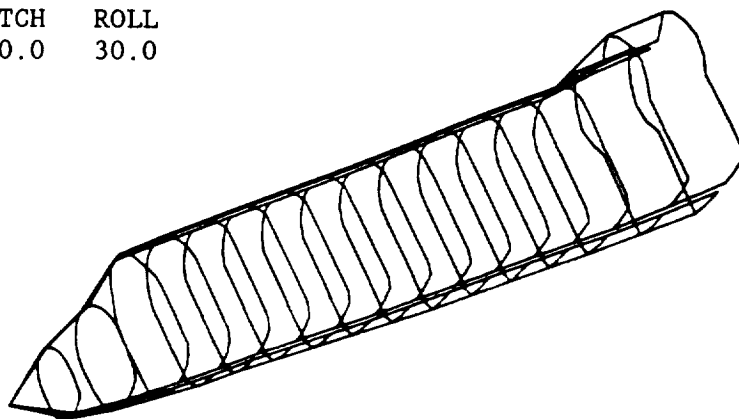


Figure 3-73. Orthographic Projection of Slender Body.

The slender body simulation for the fuselage requires a series of editing steps as outlined on figures 3-74 through 3-82. The effort is similar to that performed on the simple fuselage (see figure 3-19) and will not be repeated here.

Fuselage sectional forces and moments are governed by the axial rate of change of cross-section area. Consequently denser definition is required in such regions. When a single component is used to generate the slender body, input contours can be appropriately concentrated and editing is generally not necessary. When more than one component is used, the sections are evenly spaced between components, and some longitudinal definition can be lost. By editing in the presence of the forward fuselage (figures 3-74 and 3-75) and zooming in on the forebody (figure 3-76), the nose of the slender body is modified by adding sections and scaling them into place (figures 3-76 through 3-78).

```

**OK**
--- files
      COMPN          NAME          TYPE          SYMM
      10.00         SIMPLE FUSELAGE      1           2
      11.00         FORWARD FUSELAGE     1           2
      12.00         MID FUSELAGE          1           2
      13.00         AFT FUSELAGE          1           2
      14.00         POD                   2           2
     101.00         SIMPLE WING            4           2
     121.00         WING                   4           2
     201.00         SIMPLE VERTICAL        3           1
     211.00         VERTICAL               3           1
     611.00         SLENDER BODY           7           2
     612.00         INTERF SHELL           5           2
**OK**
--- edit 611 11
      EDIT**
--- vi

```

Figure 3-74. Slender Body Editing Using Forward Fuselage.

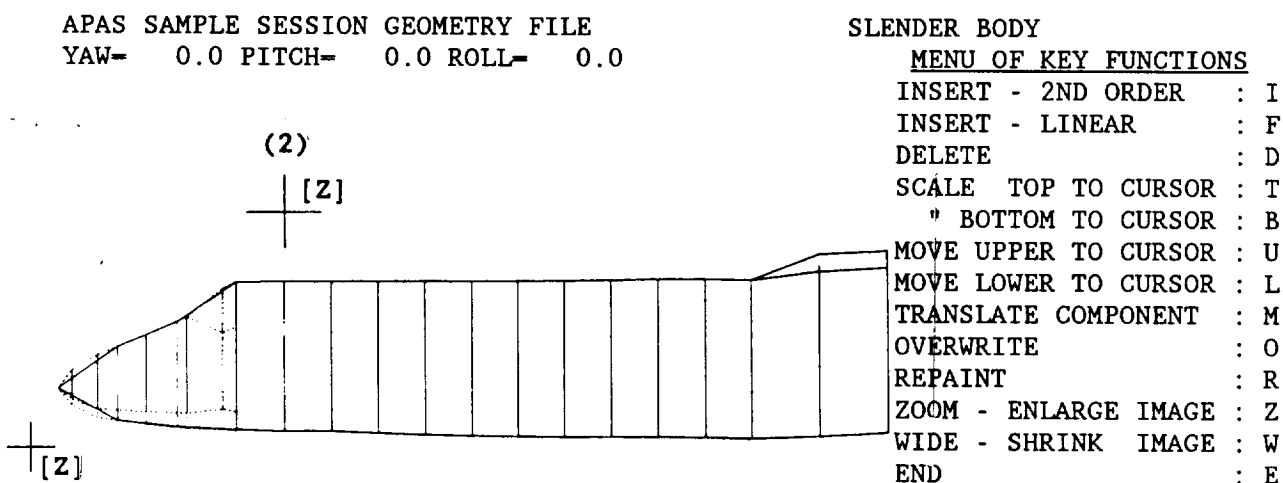


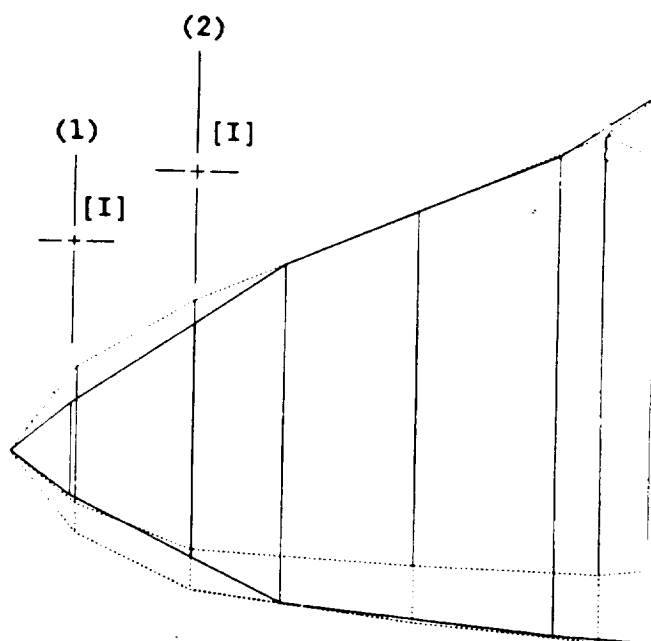
Figure 3-75. Viewing Slender Body with the Forward Fuselage (dashed line) as an Underlay.

APAS SAMPLE SESSION GEOMETRY FILE

SLENDER BODY

YAW= 0.0 PITCH= 0.0 ROLL= 0.0

MENU OF KEY FUNCTIONS



INSERT - 2ND ORDER : I
 INSERT - LINEAR : F
 DELETE : D
 SCALE TOP TO CURSOR : T
 " BOTTOM TO CURSOR : B
 MOVE UPPER TO CURSOR : U
 MOVE LOWER TO CURSOR : L
 TRANSLATE COMPONENT : M
 OVERWRITE : O
 REPAINT : R
 ZOOM - ENLARGE IMAGE : Z
 WIDE - SHRINK IMAGE : W
 END : E

Figure 3-76. Adding Sections to the Nose of the Slender Body Using the Forward Fuselage as Reference.

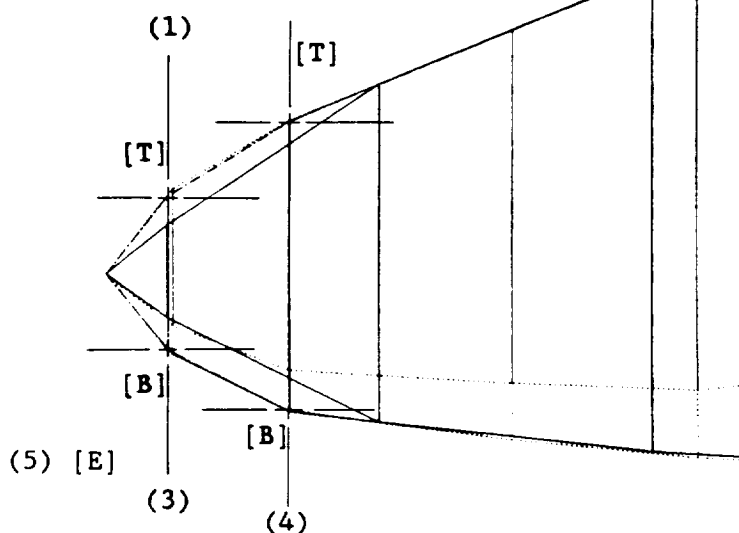
APAS SAMPLE SESSION GEOMETRY FILE

SLENDER BODY

YAW= 0.0 PITCH= 0.0 ROLL= 0.0

MENU OF KEY FUNCTIONS

EDIT**
 (6) → vi=0.,0.,90. (2)



INSERT - 2ND ORDER : I
 INSERT - LINEAR : F
 DELETE : D
 SCALE TOP TO CURSOR : T
 " BOTTOM TO CURSOR : B
 MOVE UPPER TO CURSOR : U
 MOVE LOWER TO CURSOR : L
 TRANSLATE COMPONENT : M
 OVERWRITE : O
 REPAINT : R
 ZOOM - ENLARGE IMAGE : Z
 WIDE - SHRINK IMAGE : W
 END : E

Figure 3-77. Scaling the New Sections to Match the Forward Fuselage Contours.

APAS SAMPLE SESSION GEOMETRY FILE

SLENDER BODY

YAW= 0.0 PITCH= 0.0 ROLL= 0.0

MENU OF KEY FUNCTIONS

EDIT**
(4) → s
SAVED IN PERM FILE.
EDIT**
→ end
OK
→ disp 611

INSERT - 2ND ORDER : I
INSERT - LINEAR : F
DELETE : D
SCALE TOP TO CURSOR : T
" BOTTOM TO CURSOR : B
MOVE UPPER TO CURSOR : U
MOVE LOWER TO CURSOR : L
TRANSLATE COMPONENT : M
OVERWRITE : O
REPAINT : R
ZOOM - ENLARGE IMAGE : Z
WIDE - SHRINK IMAGE : W
END : E

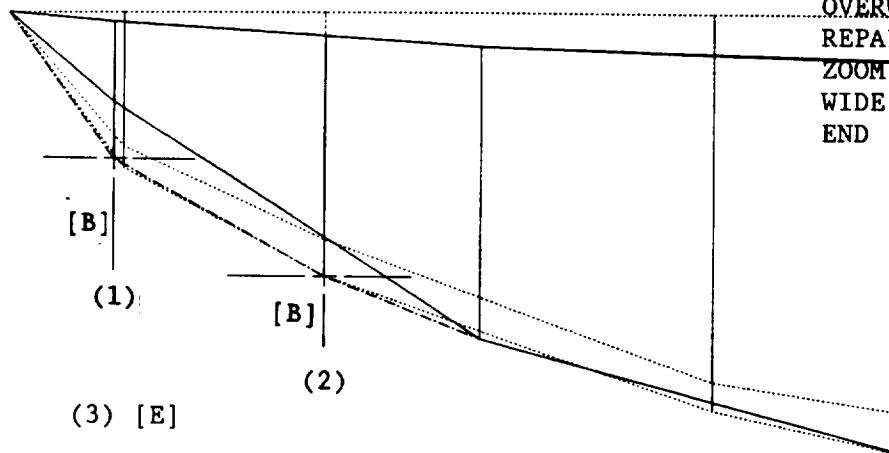


Figure 3-78. Plan View Corrections to Match Forward Fuselage.

After displaying the body (figure 3-79), it is noted that improved definition is required in the crew area and pods. Reduced mid-fuselage definition is permissible as a result of small area changes.

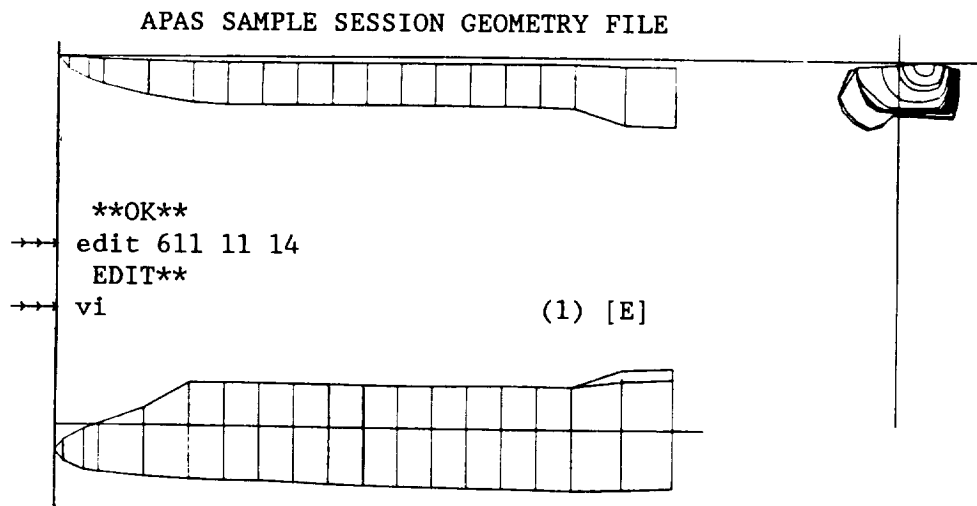


Figure 3-79. Three-view Display of Slender Body Modifications.

On figure 3-80, seven sections have been deleted from the cargo area. The fuselage is enlarged with the zoom option and section definition is improved on figure 3-81. Finally, a close-up of the forebody aids in the enhancement of the crew station area in figure 3-82.

APAS SAMPLE SESSION GEOMETRY FILE

SLENDER BODY

YAW= 0.0 PITCH= 0.0 ROLL= 0.0

MENU OF KEY FUNCTIONS

INSERT - 2ND ORDER : I
 INSERT - LINEAR : F
 DELETE : D
 SCALE TOP TO CURSOR : T
 " BOTTOM TO CURSOR : B
 MOVE UPPER TO CURSOR : U
 MOVE LOWER TO CURSOR : L
 TRANSLATE COMPONENT : M
 OVERWRITE : O
 REPAINT : R
 ZOOM - ENLARGE IMAGE : Z
 WIDE - SHRINK IMAGE : W
 END : E

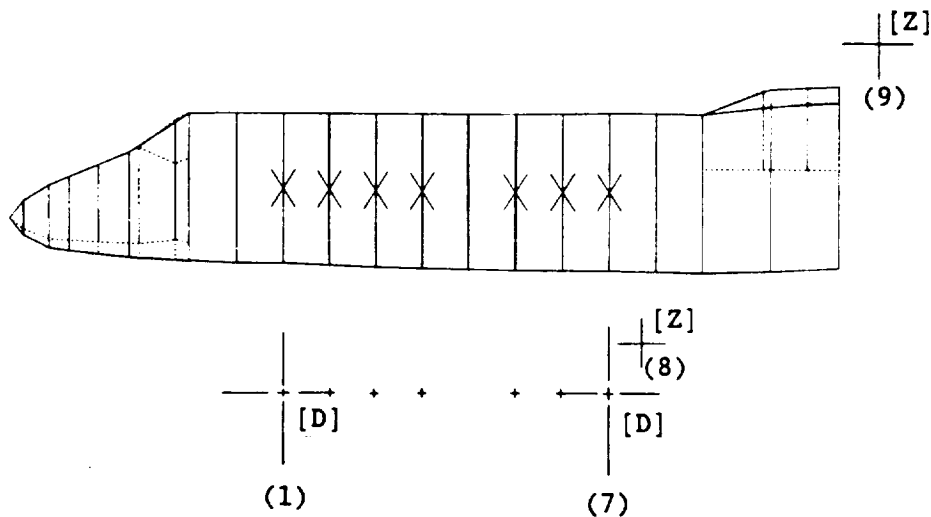


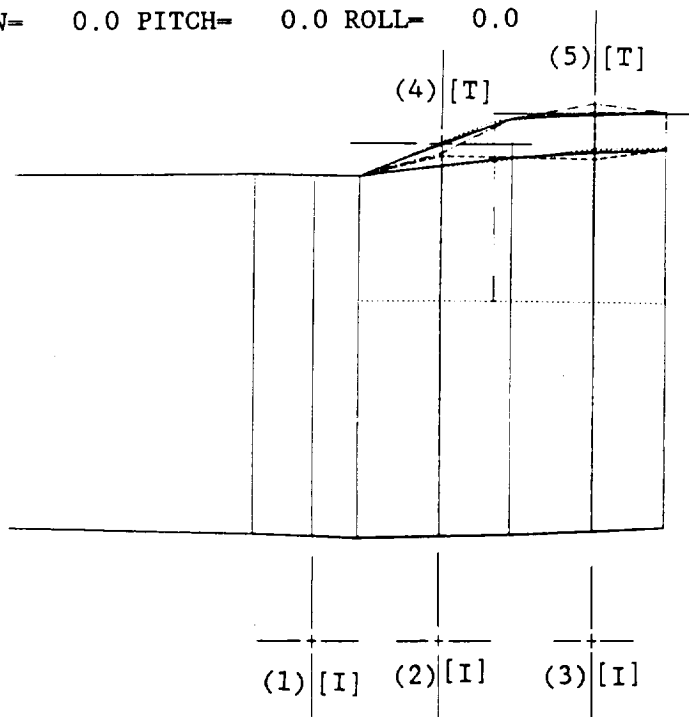
Figure 3-80. Thinning Slender Body Sections.

APAS SAMPLE SESSION GEOMETRY FILE

SLENDER BODY

YAW= 0.0 PITCH= 0.0 ROLL= 0.0

MENU OF KEY FUNCTIONS



INSERT - 2ND ORDER : I
 INSERT - LINEAR : F
 DELETE : D
 SCALE TOP TO CURSOR : T
 " BOTTOM TO CURSOR : B
 MOVE UPPER TO CURSOR : U
 MOVE LOWER TO CURSOR : L
 TRANSLATE COMPONENT : M
 OVERWRITE : O
 REPAINT : R
 ZOOM - ENLARGE IMAGE : Z
 WIDE - SHRINK IMAGE : W
 END : E

Figure 3-81. Inserting and Adjusting Sections in Aft Fuselage.

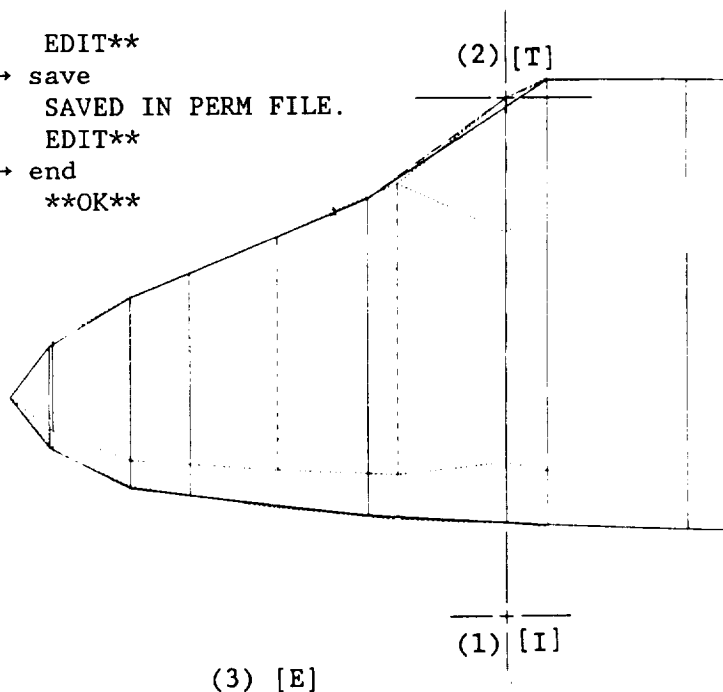
APAS SAMPLE SESSION GEOMETRY FILE

SLENDER BODY

YAW= 0.0 PITCH= 0.0 ROLL= 0.0

MENU OF KEY FUNCTIONS

EDIT**
 (4) →→ save
 SAVED IN PERM FILE.
 EDIT**
 →→ end
 OK



INSERT - 2ND ORDER : I
 INSERT - LINEAR : F
 DELETE : D
 SCALE TOP TO CURSOR : T
 " BOTTOM TO CURSOR : B
 MOVE UPPER TO CURSOR : U
 MOVE LOWER TO CURSOR : L
 TRANSLATE COMPONENT : M
 OVERWRITE : O
 REPAINT : R
 ZOOM - ENLARGE IMAGE : Z
 WIDE - SHRINK IMAGE : W
 END : E

Figure 3-82. Rounding Off the Slender Body Crew Station.

Interference Shell

The INTERFERENCE command is used to construct an interference shell using the slender body (611.00), wing (121.00), and vertical tail (211.00) auxiliary components as indicated on figure 3-83. The component number is selected to be within the same decade as the slender body component number (a program rule).

```

**OK**
--> inte 611 121 211
    ENTER COMPONENT NUMBER:
    612.

    ENTER COMPONENT NAME:
--> interf shell

```

Figure 3-83. INTERFERENCE Command General Input.

On figure 3-84, the shell is defined using the graphics cursor to input specific locations following the menu in the lower right hand side of the screen. The construction proceeds as follows.

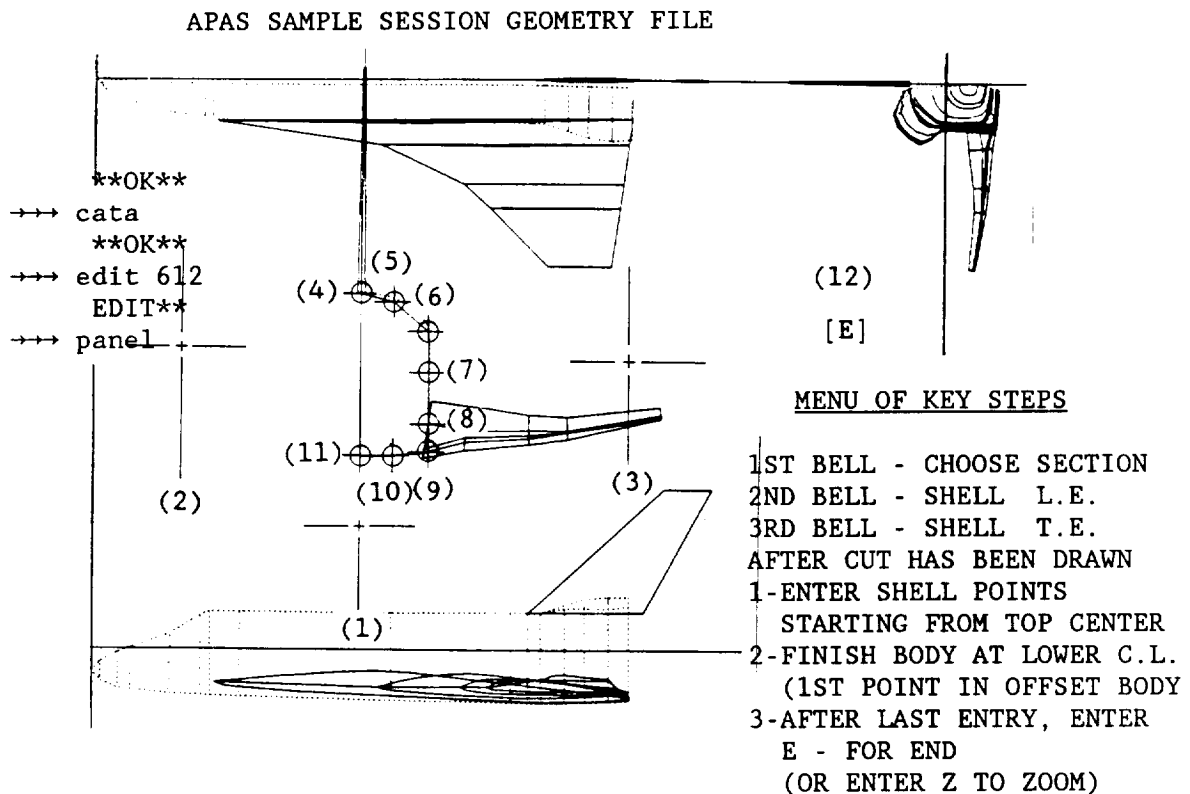


Figure 3-84. Interference Shell Construction.

Select a cross-section which is representative of the body the shell is being constructed about. For this step through step 11, the key used to enter points on the screen is arbitrary as long as it's not an E. Step 2, enter the forward most point for the shell; step three, enter the most aft.

Following step 3, the section selected in step 1 is drawn on the screen in an increased scale to facilitate the next steps. The zoom option (Z key) can be used to further enlarge the section if desired. Using the graphics cursor, points are entered (steps 4 through 11) defining the shape of the interference shell "tube". Starting from the top of the section, a point is entered to match the vertical root chord. INTERFERENCE automatically matches y and/or z values of points that are entered in proximity to any surface leading edge points. Point 5 is a free point; 6, 7 and 9 have free z values but will be matched exactly to the wing root point. The y value of point 10 will match point 5, and point 11 will be matched to $y = 0.0$. Step 12 ends the construction with the entry of an E. The shell is cataloged to save it.

Paneling

The shell is paneled using the PANEL subcommand of EDIT. The keyboard and graphics entries are shown on figure 3-85. The shell regions are numbered from 1 to 7. Keyboard entries are labeled by step on the outside of the picture border and graphics entries are shown inside. Steps 2 through 8 enter the number of spanwise panels in each region. Entries 9 through 15 describe the chordwise paneling and control surfaces of each region. The interference shell cannot have control surfaces, so only the first two values in each entry (NCHRD-number of chordwise panels and NSPACE-chordwise spacing: 1-even, 2 half cosine and 3-cosine spacing) are used. These have default values of 10 and 1, respectively. The axial paneling of the shell should be geometrically similar to the wing and vertical, NCHRD=15 was selected to improve the simulation. When 15 is entered in step 9, it replaces NCHRD=10 as the default, and a carriage return is all that is required in entries 10 through 15 to set regions 2 through 7 at similar even chordwise spacing. A copy can be made for record purposes before executing step 16. Note: a minimum of 3 chordwise panels are required.

The wing and vertical tail are paneled on figures 3-86 and 3-87. A control surface line is defined in steps 1 (1') and 2 (2') using the C key to indicate a x/c value will be input for each selected chord from the keyboard. Since the control surface line is straight, the root and tip chord are used for construction. Notice that the chord selected will be the one closest to the graphics cursor, indicated by the offset locations shown in steps 1 and 2 on the screen. Steps 1' and 2' are entered immediately following their respective graphics steps. The spanwise entries (steps 5 through 8) are the same as previously discussed for the shell. Notice in steps 9 through 16 of figure 3-86 that the PANEL subcommand scans through the leading edge regions first (regions 1, 3, 5 and 7), then the trailing edge (flap regions 2, 4, 6 and 8). This allows the user to set up two sets of defaults, one for the forward regions (steps 9 through 12) and one for the flap regions (steps 13 through 16). NCHRD and NSPACE have already been discussed. NFLAP is the flap number (1 through 6) of the region, and SFLAP is the flap symmetry indicator (1 for symmetric, -1 antisymmetric, or 0 for both-which counts as two flaps). The wing control surface (flap 1) is a symmetric flap, and the vertical tail rudder (flap 2) is antisymmetric.

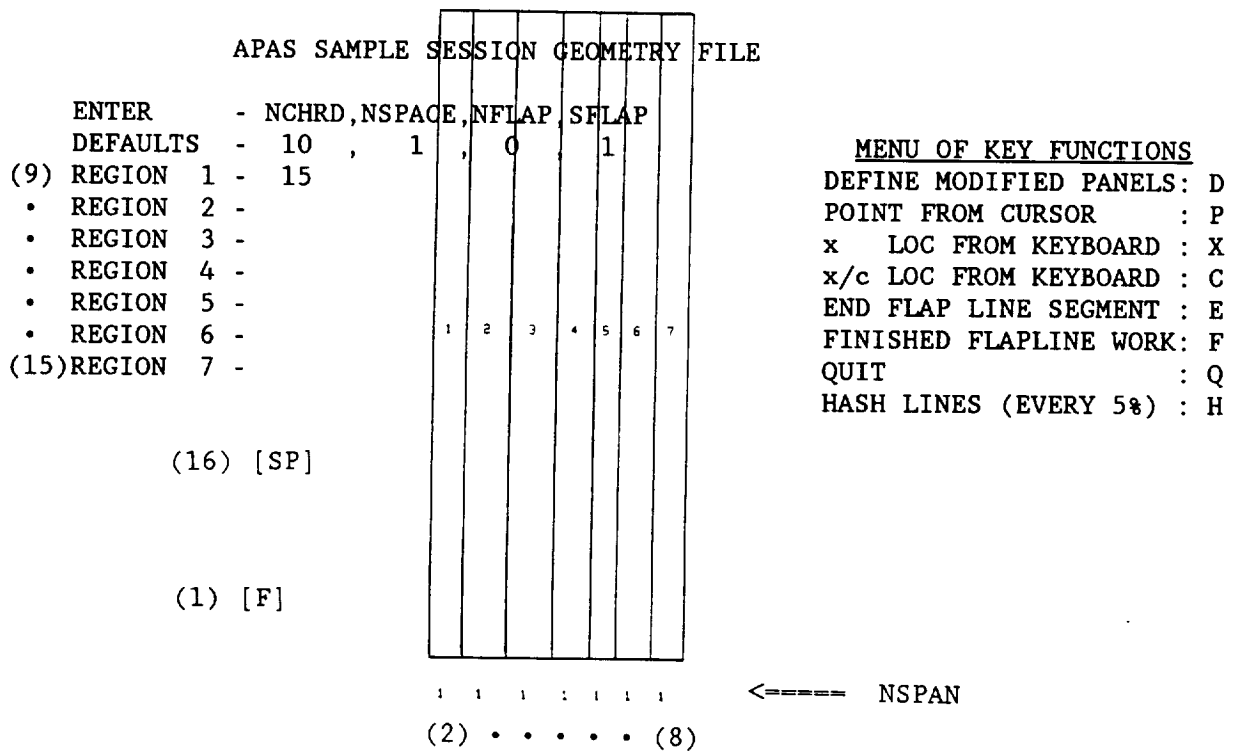


Figure 3-85. Interference Shell Paneling.

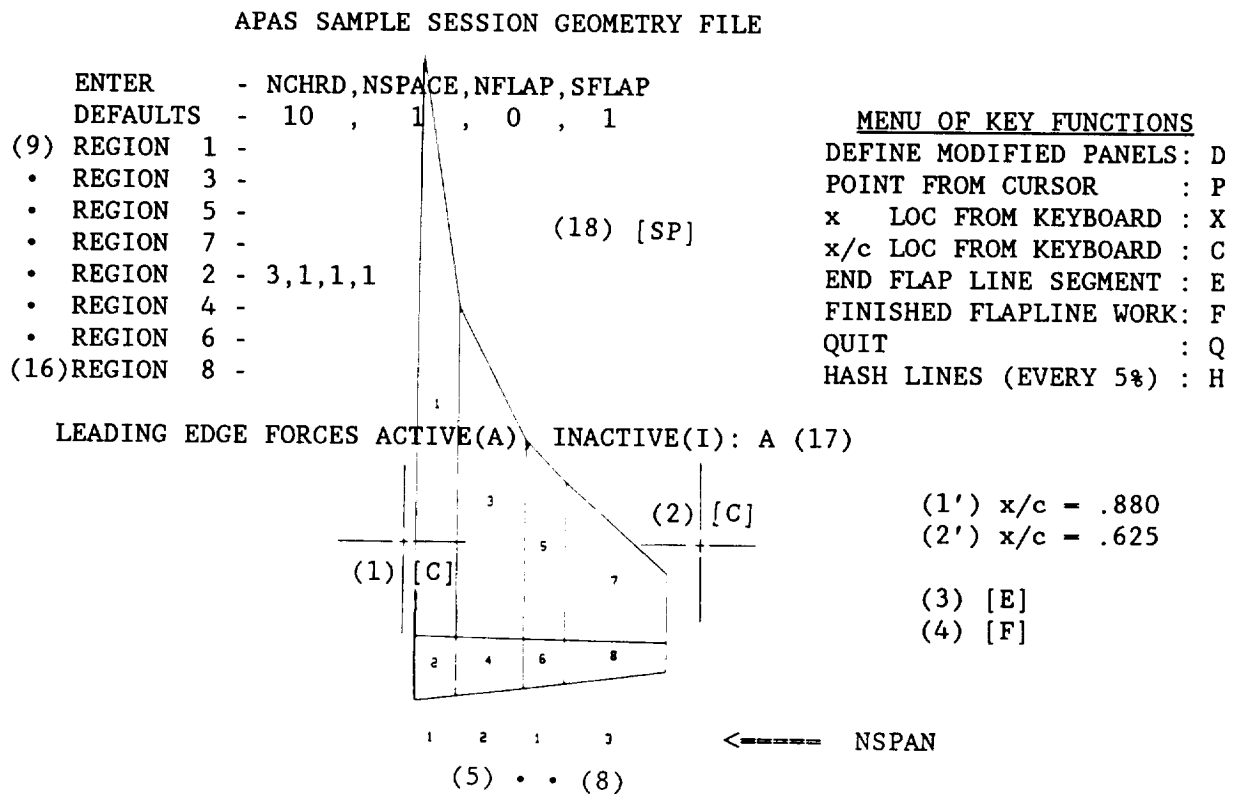


Figure 3-86. Wing-flap Paneling.

Construction of a partial span flap is accomplished by first positioning the cross hairs near the pertinent inboard section and entering a C and then repeating the process near the appropriate outboard section. For a case without flaps, the cross hairs is placed behind the trailing edge of the root and tip and a P entered each time. Termination of either case is the same as full span flap of figure 3-86 (i.e. steps 3 and 4). All APAS flap deflections are in the freestream direction and not relative to the hinge line. So, if the user has tunnel flap deflections measured relative to the hinge line the input angles for APAS would be those deflections times cosine of the hinge line angle.

A constant source panel default is used for calculating thickness effects. If it is changed to a linear axial variation in the SET command, the flap hinge line must be on a constant fractional chord line.

The declaration of leading and side edge vortex forces at subsonic-supersonic speeds is defined for the wing and vertical tail by step 17 of figure 3-86 and step 8 of figure 3-87 respectively.

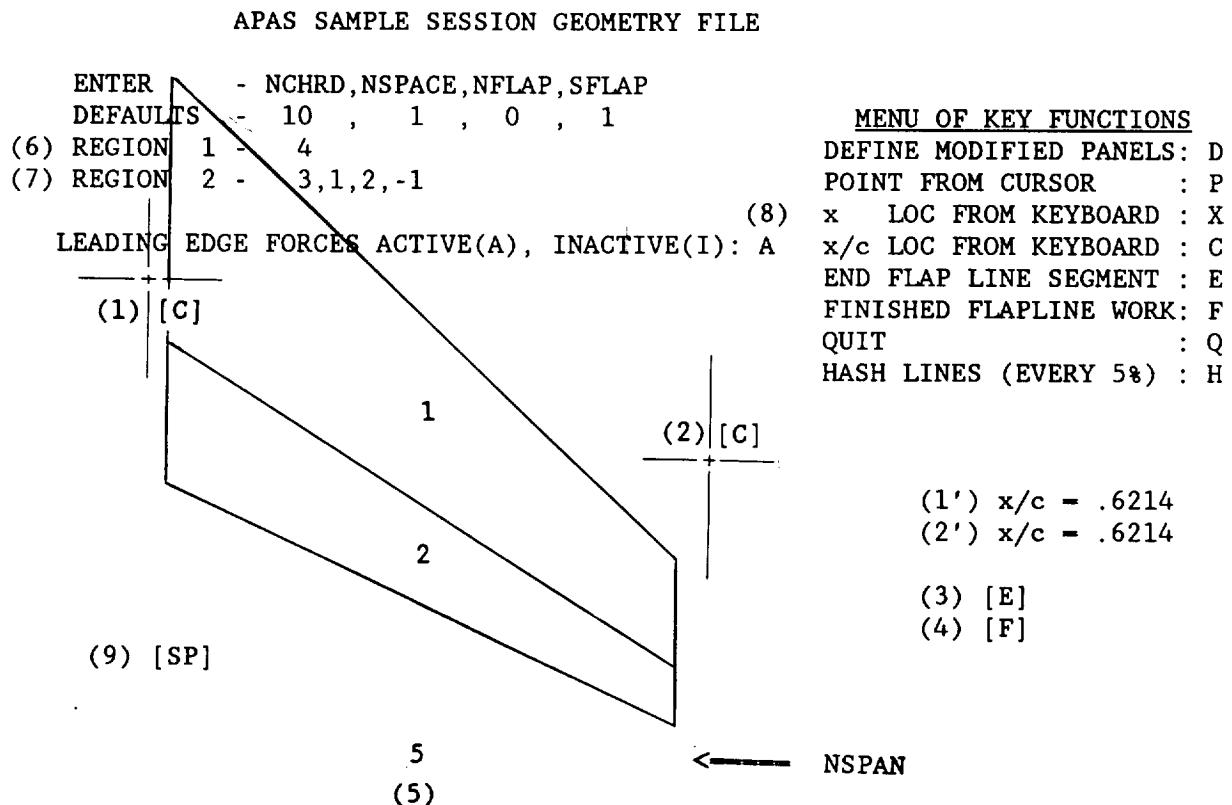


Figure 3-87. Vertical Tail-flap Paneling.

The permanent geometry file now contains all the components necessary to assemble a complete configuration for analysis. The beginning user will find it beneficial to take some of the components that have been generated and manipulate and modify them using the command dictionary for options not explicitly covered in this session. These practice components can be subsequently discarded.

SECTION IV

ANALYSIS

Aerodynamic analysis is based on the theory described in Part I. Components ATTACHed to the local file define a configuration. Limited analysis (drag only) may be accomplished in the foreground, otherwise the configuration is evaluated via a background job submittal once the SET command has been entered and the user has defined a series of runs.

Subsonic-supersonic and/or hypersonic evaluation may be conducted for a requested background analysis. Calculations are automatically processed in a manner which minimizes computational cost and is independent of the run schedule order.

Foreground drag analysis is available for precursor configuration screening purposes and will be discussed initially. The procedures for developing a background set up are then defined. Finally, a set of sample sessions is presented to familiarize the user with the various analysis capabilities of the system.

FOREGROUND

Skin friction and wave drag evaluation can be conducted interactively to facilitate vehicle/major component screening prior to full background analysis.

The VISCOUS command defines vehicle distributions of perimeter and cross-section area as well as component and total vehicle surface area and volume. Evaluation of the skin friction for specified flight conditions is then performed.

The WAVEDRAG command evaluates the wave drag due to volume at supersonic speeds using the area rule. This information is used to determine if vehicle or component reconfiguration should be pursued prior to batch analysis.

The first sample session (pages 82 through 89) illustrates typical input directives and output results for the interactive drag analysis.

BACKGROUND SETUP

The SET command is used to define a schedule of runs to be analyzed. It also processes requests to display the aerodynamic models for verification, define required constants, and select hypersonic panel algorithms prior to dispatching the background input file (generally referred to as the plot file since certain data generated in background are stored in this file for later plotting ,i.e., once the foreground part of APAS is re-entered) for processing.

The SET subcommand of SET permits the user to store up to twelve (12) lists that are commonly used for analysis runs. A list in this context is a

set of parameters describing flight or wind-tunnel conditions, initial attitudes for static and rotary derivatives, and variable values of angle of attack or sideslip.

The batch input file accommodates thirty-two separate runs or 292 data points (i.e., $[\alpha, \beta]$ combinations). The maximum number of data points per run is 20. The choice of independent variables has been limited to two, angle of attack and sideslip.

The LIST subcommand of SET command provides the user with a list of runs in the batch input file attached to the system, giving all non-zero initial conditions and the status (whether analysis has taken place or not) of each run. If a run is to be recomputed, the RESET subcommand is used to return that run to analysis status.

Aerodynamic model verification and hypersonic panel algorithm selections have been built into SET and follow after using the END subcommand. The user can temporarily skip this portion of SET if he is not ready for analysis or simply reviewing the run schedule. The logic must however be processed prior to analysis, but this is necessary for only the first time a component has been designated for a hypersonic analysis.

The selected hypersonic panel methods are stored as part of the component geometry and cannot be changed from run to run or configuration to configuration. They can be parametrically varied by making several analysis passes adding new runs each time and changing the analysis methods prior to each batch submittal. Analysis print provides a record of the methods used.

The standard print from analysis provides summary type data. If a hypersonic run is questionable, it can be reactivated with the PRINT operand specified in the RESET subcommand, and detailed print will result. This will increase the number of output lines for that run by a factor of almost ten and is only recommended for diagnostic purposes.

The second sample session (pages 90 through 104) illustrates configuration assembly, run schedule definition and aerodynamic model validation for background analysis.

SAMPLE SESSIONS

Precursor drag analysis and setup for background submittal are presented to familiarize the analyst with these system activities.

FOREGROUND (SESSION 4-1)

Review the VISCOUS and WAVEDRAG commands of section six prior to beginning this session.

A configuration is selected from the permanent file listing on figure 4-1 and attached to the local file. Note the use of the "g" key to attach all components in family 11.00 (i.e. 11.00-20.00). A list of the local file verifies the configuration and the VISCOUS command is entered, fourth entry. Option 3 (the default) is used to evaluate the surface area and volume using 51 equally spaced axial section cuts. Figures 4-2 and 4-3 present the resulting perimeter and cross-section area distribution. Component and total areas and volumes are also tabulated.

The following message is then presented on the screen:

```
0  EXIT
1  SF DRAG
2  EDIT
```

Selecting option 1, the skin friction setup is completed as shown in figure 4.4. A surface roughness of 0.00000634 meters corresponding to carefully applied mate paint (see table 9 in section 6 under VISCOUS command) has been entered. For the altitudes of 0.0, 3048, and 6096 meters the user requests detailed print at sea level, $M = 0.6$ and $h = 3048$ meters, $M = 1.2$ and no printout at $M = 1.6$. The viscous-drag default parameters are accepted for each component.

Figures 4-5 and 4-6 present the output requested at $M = 0.6$ and 1.2 respectively. Surface wetted areas are calculated in the viscous drag analysis using a component strip integration as opposed to the total configuration axial section integration of figures 4-2 and 4.3. The component wetted areas may differ slightly from those of figure 4-7, since the latter is based on figure 4-2. Figure 4-7 presents a summary of the drag, surface area, and volume for the configuration in the local file. The user ends the VISCOUS command with a "0" on figure 4-8.

```

**OK**
--- files
      COMPN          NAME          TYPE          SYMM
      10.00         SIMPLE FUSELAGE      1          2
      11.00         FORWARD FUSELAGE     1          2
      12.00         MID FUSELAGE         1          2
      13.00         AFT FUSELAGE         1          2
      14.00         POD                  2          2
      101.00        SIMPLE WING           4          2
      121.00        WING                 4          2
      201.00        SIMPLE VERTICAL       3          1
      211.00        VERTICAL              3          1
      611.00        SLENDER BODY         7          2
      612.00        INTERF SHELL         5          2
**OK**
--- attach llg      121  211
**OK**
--- file,1
      COMPN          NAME          TYPE          SYMM
      11.00         FORWARD FUSELAGE     1          2
      12.00         MID FUSELAGE         1          2
      13.00         AFT FUSELAGE         1          2
      14.00         POD                  2          2
      121.00        WING                 4          2
      211.00        VERTICAL              3          1
**OK**
--- visc
      KEY * 1,2, OR 3
      1 * PLOT * NX, X(1),.....,X(MX)
      2 * PLOT * NX,XB,XE
      3 * NO PLOT * MX-51 (ALL SURFACE FLAGED)
--- 3

```

Figure 4-1. Assembling Local File Configuration and Initiating the VISCOUS Command.

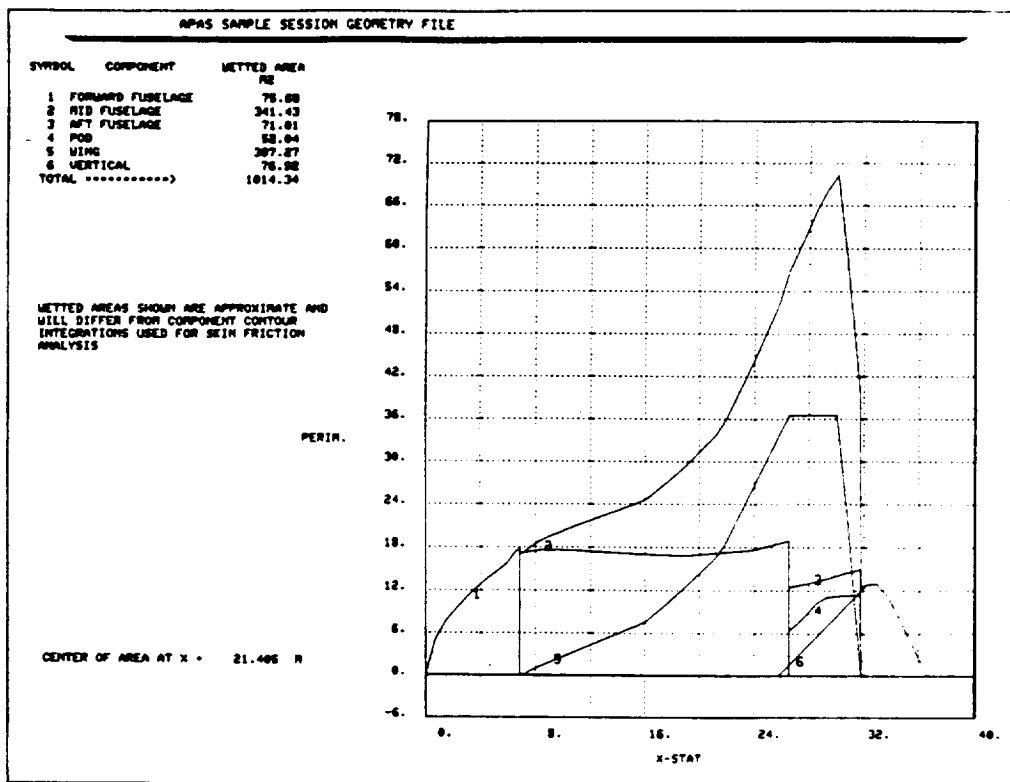


Figure 4-2. Perimeter Distribution and Wetted Area.

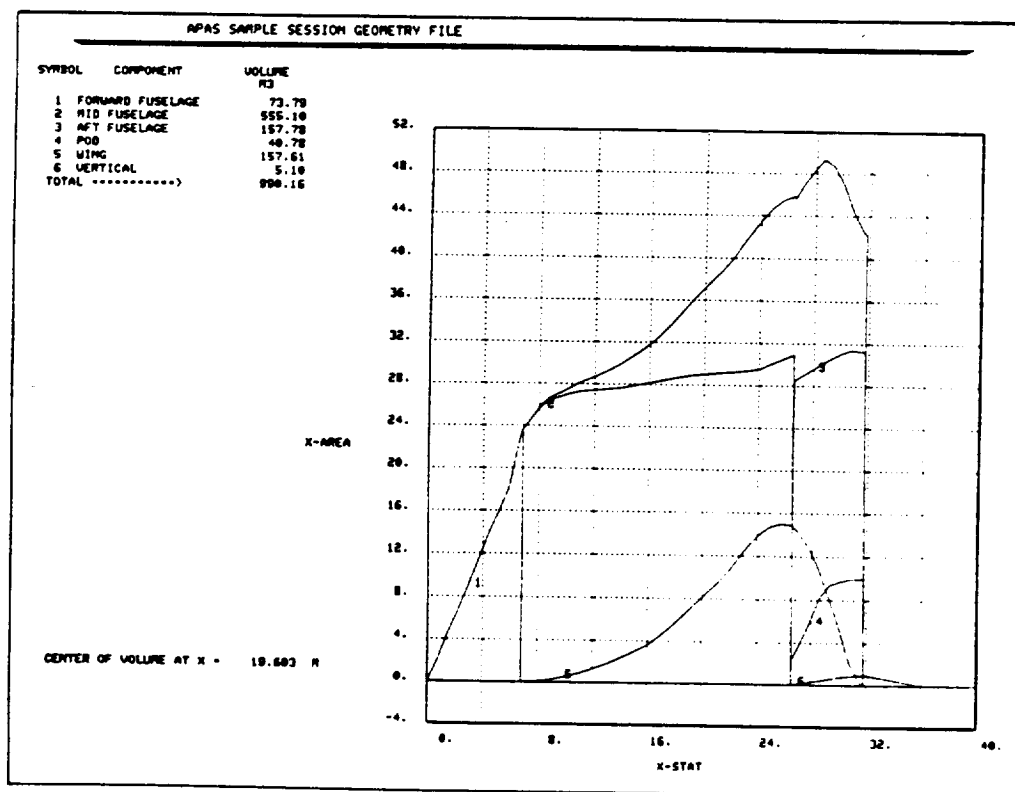


Figure 4-3. Area Distribution and Volume.

```

SKIN FRICTION DRAG INPUT
  INPUT MACH NUMBERS:
--> 0.6 1.2 1.6
  INPUT SREF( M2):
--> 249.91
  ENTER SAND GRAIN HEIGHT (KS( M)) DEFAULT: 0.0
--> 0.00000634
  ENTER STAG PRESS(NT/M2), TEMP(K), LISTING MACH NUMBER (0.0 FOR ALL)
  OR ENTER ALTITUDE( M), LISTING MACH NUMBER
  ENTER CARRIAGE RETURN TO END
  ENTER DATA FOR CASE 1
--> 0 0.6
  ENTER DATA FOR CASE 2
--> 3048 1.2
  ENTER DATA FOR CASE 3
--> 6096
  ENTER DATA FOR CASE 4
--> <CR>
  FORWARD FUSELAGE ENTER: XTRANS/LENG, FLAT PLATE1 * AXIS-BODY 2 :
  DEFAULTS : 0.01,2
--> <CR>
          BODY FORM FACTOR : 1.07688
          BODY T/C RATIO : 0.12223
  WING          ENTER: XTRANS/LENG, CK, FLAT PLATE 1 * AIRFOIL 2 :
  DEFAULTS : 0.01,1.2,2
--> <CR>
  VERTICAL          ENTER: XTRANS/LENG, CK, FLAT PLATE 1 * AIRFOIL 2 :
  DEFAULTS : 0.01,1.2,2
--> <CR>

```

Figure 4-4. VISCOUS Calculation Input Parameters.

APAS SAMPLE SESSION GEOMETRY FILE

MACH: 0.600	ALT: 0. M	PRESS: 101324.125	NT/M2	TEMP: 288.149	K	SREF: 249.910	M2	KS: 0.00000634	M
COMPONENT	WET SURF	COMP	FF	X/L	REYNOLDS	CDF	CDF	CDF	
	AREA M2	LENGTH M		TRANS.	NO.	SMOOTH	ROUGH	USED	
FORWARD FUSELAGE	540.2	31.750	1.077	0.010	4.43729E+08	0.00380	0.00375	0.00380	
WING	126.4	20.100	1.100	0.010	2.80909E+08	0.00097	0.00096	0.00097	
WING	123.6	12.573	1.129	0.010	1.75723E+08	0.00103	0.00103	0.00103	
WING	50.0	8.695	1.146	0.010	1.21519E+08	0.00045	0.00044	0.00045	
WING	83.0	5.707	1.137	0.010	7.97581E+07	0.00078	0.00078	0.00078	
VERTICAL	77.2	4.808	1.048	0.010	6.71999E+07	0.00068	0.00069	0.00069	
** TOTAL WET SURFACE AREA = 1000.45 M2									
** TOTAL SKIN FRICTION DRAG = 0.00771									

Figure 4-5. VISCOUS Detailed Print at M = 0.6.

```

APAS SAMPLE SESSION GEOMETRY FILE

```

```

MACH: 1.200  ALT: 3048. M  PRESS: 60692.562 NT/M2  TEMP: 268.347 K  SREF: 249.910 M2  KS: 0.00000634 M
COMPONENT      WET SURF  COMP  FF      X/L      REYNOLDS      CDF      CDF      CDF
                  AREA M2  LENGTH M                  TRANS.      NO.      SMOOTH      ROUGH      USED
FORWARD FUSELAGE  540.2    31.750  1.077  0.010  6.68347E+08  0.00331  0.00318  0.00331
WING              126.4    20.100  1.100  0.010  4.23424E+08  0.00084  0.00081  0.00084
WING              123.6    12.573  1.129  0.010  2.64873E+08  0.00090  0.00087  0.00090
WING              50.0     8.695  1.146  0.010  1.83170E+08  0.00039  0.00038  0.00039
WING              83.0     5.707  1.137  0.010  1.20222E+08  0.00068  0.00068  0.00068
VERTICAL          77.2     4.808  1.048  0.010  1.01293E+08  0.00060  0.00058  0.00060

```

```

** TOTAL WET SURFACE AREA = 1000.45 M2
** TOTAL SKIN FRICTION DRAG = 0.00671

```

Figure 4-6. VISCOUS Detailed Print at M=1.2.

APAS SAMPLE SESSION GEOMETRY FILE

VISCOUS DRAG

ALTITUDE	TEMPERATURE	PRESSURE	0.60	MACH NUMBERS	
				1.2	1.6
0.0	288.149	.1013E+06	0.00771	0.00650	0.00577
3048.0	268.347	.6969E+05	0.00801	0.00671	0.00599
6096.0	248.564	.4660E+05	0.00835	0.00699	0.00624

NUMBER	NAME	SWET M2	VOLUME M3
11.00	FORWARD FUSELAGE	75.679	73.791
12.00	MID FUSELAGE	341.426	555.096
13.00	AFT FUSELAGE	71.009	157.785
14.00	POD	52.037	40.785
121.00	WING	383.077	157.611
211.00	VERTICAL	77.220	5.097
TOTALS:		1000.448	990.163

SAND GRAIN HEIGHT: 0.00000634 M

REFERENCE AREA: 249.91 M2

Figure 4-7. VISCOUS Summary Print.

Entering the WAVEDRAG command, second entry, a request is made for the supersonic Mach numbers to be calculated and the reference area, last two entries on figure 4-8. Figures 4-9 and 4-10 present WAVEDRAG output for the specified Mach numbers. Twenty five roll angles are calculated and the drag for every other one and the total drag are printed on the upper left. Area plots as a function of x are presented for 45 degree roll angle increments. Following the last Mach number, the WAVEDRAG command returns control to the **OK** mode, and the user is ready to exit or continue into analysis session 4-2. To initiate this effort either clear the work file using the CLEAR command and start at the top of figure 4-11 or attach only components 611.00 and 612.00 and start with the third entry (file,1) on figure 4-11. Note that the configuration including 611.00 and 612.00 could have been attached at the beginning of this session since VISCOUS and WAVEDRAG ignore analysis components.

```

* 0 EXIT
* 1 SF DRAG
* 2 EDIT
--> 0
**OK**
--> wave
    INPUT MACH NUMBERS:
--> 1.2 1.6
    INPUT SREF (M2):
--> 249.91

```

Figure 4-8. Exiting VISCOUS and Entering WAVEDRAG Command.

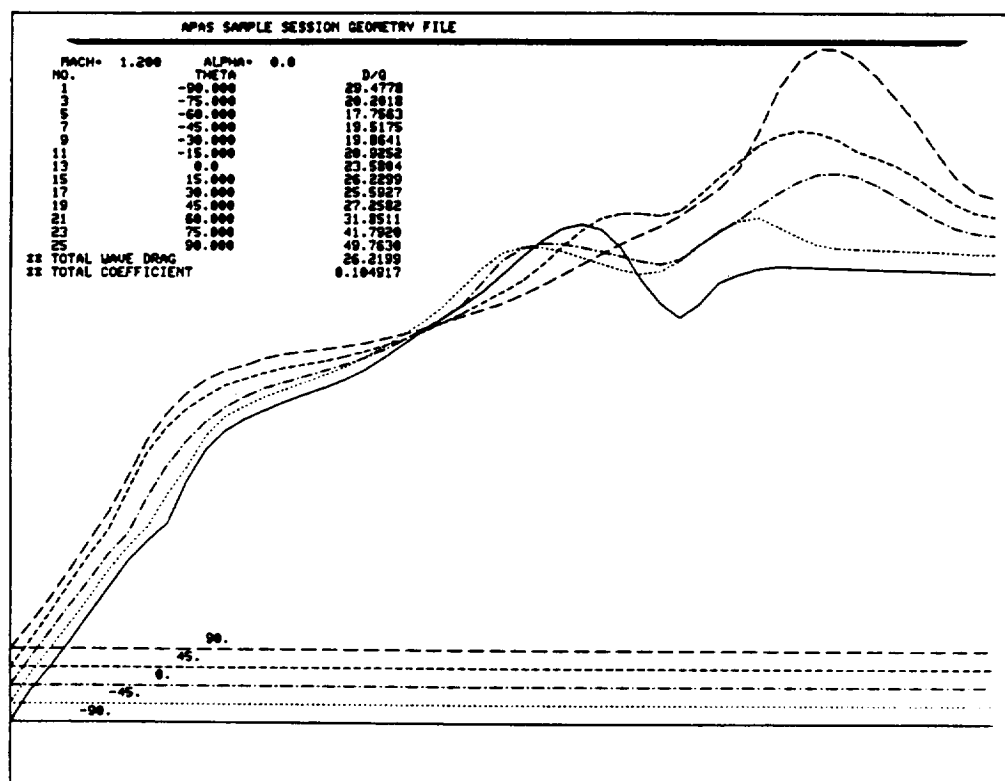


Figure 4-9. WAVEDRAG Output at M=1.2.

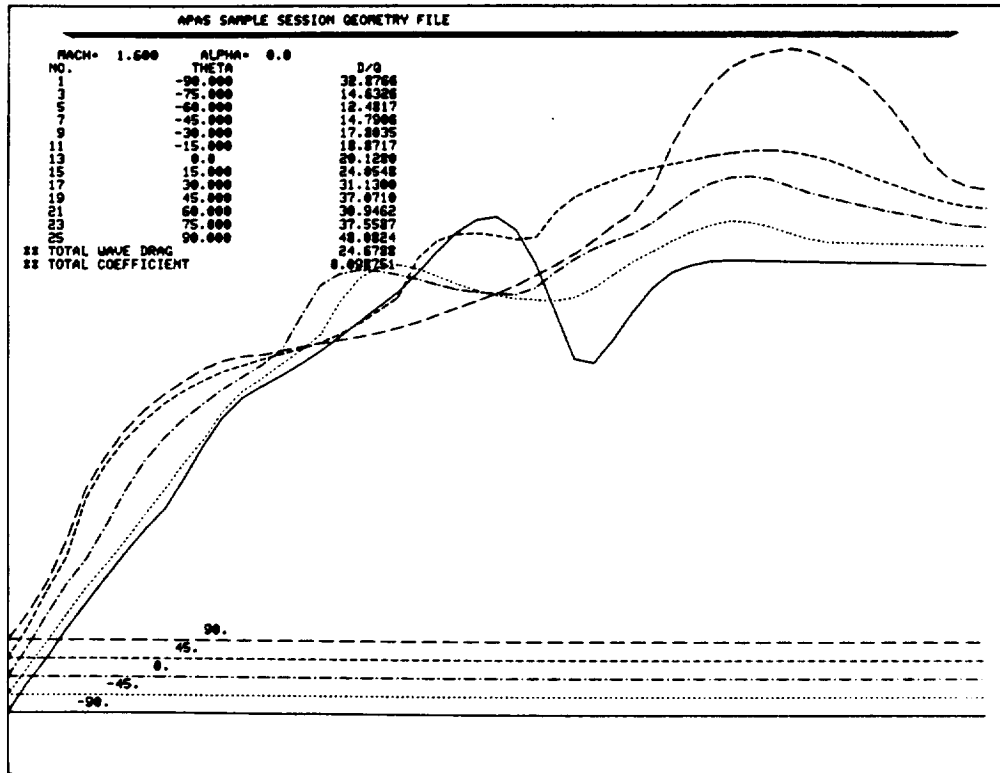


Figure 4-10. WAVEDRAG Output at M=1.6.

BACKGROUND ANALYSIS (SESSION 4-2)

Review the SET command of section six prior to beginning this work session.

Subsonic-Supersonic Configuration

During this effort the user assembles a configuration in the local file and then enters the SET command to define an analysis run schedule. Several of the subcommands of SET are demonstrated to familiarize the analyst with this activity.

In figure 4-11 the user attaches the digitized configuration developed in geometric input session 3-2 to the local file. The SET command of the system recognizes this as configuration 1 and requests the reference quantities to be used for aerodynamic coefficients.

To simplify run schedule preparation, the SET subcommand of SET allows the user to store up to twelve commonly used lists of run variables. Upon entering the SET subcommand (figure 4-11) the system requests the data to be stored in location one. The conditions typically entered are those that will be repetitively used. The analyst then proceeds to define additional sets two through four by calling them out directly as SET2, etc.

Set four is modified in figure 4-12 by defining input for three runs using the ADD subcommand of SET. A set may be deleted using the DELETE subcommand of SET, i.e. DEL,SET2 for example.

```
      **OK**
----> files
      COMPN          NAME          TYPE          SYMM

      10.00          SIMPLE FUSELAGE          1          2
      11.00          FORWARD FUSELAGE          1          2
      12.00          MID FUSELAGE          1          2
      13.00          AFT FUSELAGE          1          2
      14.00          POD          2          2
      101.00          SIMPLE WING          4          2
      121.00          WING          4          2
      201.00          SIMPLE VERTICAL          3          1
      211.00          VERTICAL          3          1
      611.00          SLENDER BODY          7          2
      612.00          INTERF SHELL          5          2
      **OK**
```

```

--> attach 11 12 13 14 121 211 611g
      **OK**
--> file,1
      COMPN          NAME          TYPE          SYMM
      11.00          FORWARD FUSELAGE      1          2
      12.00          MID FUSELAGE          1          2
      13.00          AFT FUSELAGE          1          2
      14.00          POD                   2          2
      121.00         WING                   4          2
      211.00         VERTICAL               3          1
      611.00         SLENDER BODY          7          2
      612.00         INTERF SHELL          5          2
      **OK**
--> set
      CONFIGURATION IN WORK FILE IS CONFIGURATION NUMBER: 1
      ENTER SREF,CBAR,SPAN:
--> 249.91,12.060,23.791
      ENTER XCG, YCG, ZCG :
--> 21.354,0.0,-0.635
      DEFAULT CONFIGURATION IS : 1
      ENTER THE FOLLOWING PARAMETERS IN THE INDICATED UNITS:
          ALTITUDE(ALT)      : METERS
      OR STAG PRESSURE(PR)   : MT/M2
      & STAG TEMPERATURE(TEMP): KELVIN
          ROUGHNESS (KS)     : METERS
      ** SET **
--> set
      ENTER LIST OF RUN VARIABLES FOR SET1
--> m(0.6),ks(0.00000634),alt(0),a(0 5 10 20)
      ** SET **
--> set2 m(1.2) alt(3048) ks(0.00000634) a(0 5 10 20 30)
      ** SET **
--> set3 m(20) alt(30488) a(0 5 10 20 30)
      ** SET **
--> set4 mach(0.8) alt(3049) a(0 5 10 20)
      ** SET **

```

Figure 4-11. Assembling a Configuration and Initiating the SET Command and Subcommand.

The subcommand ADD4 presents most of the parameters required for run 1. The 4 immediately after the word ADD refers to set4 of figure 4-11. The parameters in the run(1) ADD4 statement are in addition to set4 data and will override any redundant parameters. The sand grain height (ks) was input (table 9 under VISCOUS command description) by ADD since it is missing in set4. In figure 4-12, the UDP analysis option menu immediately follows the carriage return from this subcommand and allows the user to specify additional parameters for the run. Item two (2) is selected which requests aerodynamic characteristics for an alpha sweep. The second ADD4 statement creates run(2) and modifies the set4 Mach number from 0.8 to 1.6. Since roughness was not specified, the system request this information in the next entry. A run number will also be requested if one is not provided and will not allow duplicates.

```

** SET **
--> add4 run(1) ks(0.00000634)

*****
*
*          ****  UDP ANALYSIS OPTION MENU  ****
*
*  0 - USE PREVIOUSLY DECLARED OPTIONS/ELSE: COMPLETELY RESET
*  1 - PRINT WING L.E. SUCTION DETAILS
*  2 - CALCULATE SYMMETRICAL MATRIX FOR ALPHA INFLUENCE
*  3 - CALCULATE ASYMMETRICAL MATRIX FOR YAW INFLUENCE
*  4 - USE EXTERNAL SOURCE FOR TWIST AND CAMBER
*  5 - INVOKE JET FLAP CAPABILITY
*  6 - INVOKE INLET-MASS-FLOW-RATIO SIMULATION CAPABILITY
*  7 - INVOKE GROUND-EFFECT CAPABILITY (MIRROR IMAGES CONFIG.)
*  8 - DECLARE INACTIVE/ACTIVE STATUS FOR PANELLED COMPONENTS
*      (DEFAULT - ALL ARE ACTIVE - 1)
*  9 - USE ZERO THICKNESS FOR PANELLED COMPONENTS
*
*      EG:  1 2
*****
--> 2
RUN:      1 REFERENCE VALUES:
MACH = 0.800  PRESSURE = 69683.687  TEMP = 268.340  ALTITUDE = 3049.000
BETA = 0.0    P      = 0.0    Q      = 0.0    R      = 0.0
D1  = 0.0    D2      = 0.0    D3      = 0.0    D4      = 0.0
DS  = 0.0    D6      = 0.0    KS      = 0.0000
INDEPENDENT VARIABLE: ALPHA  4 POINTS
      0.0      5.000      10.000      20.000
** SET **
--> add4 run(2) mach(1.6)
      ENTER VALUE FOR KS
--> 0.00000634
[  ***  UDP MENU  ***  ]
--> 2
RUN:      2 REFERENCE VALUES:
MACH = 1.600  PRESSURE = 69683.687  TEMP = 268.340  ALTITUDE = 3049.000
BETA = 0.0    P      = 0.0    Q      = 0.0    R      = 0.0
D1  = 0.0    D2      = 0.0    D3      = 0.0    D4      = 0.0
DS  = 0.0    D6      = 0.0    KS      = 0.0000
INDEPENDENT VARIABLE: ALPHA  4 POINTS
      0.0      5.000      10.000      20.000
** SET **

```

Figure 4-12. Creating a Run Schedule Using the ADD Subcommand.

In the first entry of figure 4-13, the RESET subcommand of SET is used to modify run 1 by changing the Mach number to 1.6 (to match run 2) and deflecting the flap 10 degrees. This change reduces the computation costs for this analysis case, since only one Mach solution will be required in the subsonic-supersonic evaluation. Next, the analysis options menu is displayed and item 2 is selected.

In the next two entries on figure 4-13, a list of the runs and configurations in the file are requested and displayed. Note that the system assigns flap designations to the user-defined flap numbers.

```

** SET **
--> reset run(1) m(1.6) d1(10)
RUN: 1 REFERENCE VALUES:
  MACH = 1.600  PRESSURE = 69683.687  TEMP = 268.340  ALTITUDE = 3049.000
  BETA = 0.0    P      = 0.0    Q      = 0.0    R      = 0.0
  D1  = -10.0000 D2    = 0.0    D3    = 0.0    D4    = 0.0
  DS  = 0.0    D6    = 0.0    KS    = 0.0000
INDEPENDENT VARIABLE: ALPHA 4 POINTS
      0.0      5.000 10.000 20.000
** SET **
[ *** UDP MENU *** ]
--> 2

--> 1,r
RUN: 1 SET FIXED SOURCES
  MACH : 1.600 PRESSURE = 69684  TEMP = 268.34  ALTITUDE = 3049.0
  CONFIG: 1 IND. VAR.: ALPHA
      .0      5.000 10.000 20.000
  INITIAL CONDITIONS:
  D1 : 10.000 KS : .63400E-06
REYNOLDS NUMBER=891710000.0 TWALL=405.73 VBAR=0.0000 M/SQRN(RN)=0.0001

RUN: 2 SET FIXED SOURCES
  MACH : 1.600 PRESSURE = 69684  TEMP = 268.34  ALTITUDE = 3049.0
  CONFIG: 1 IND. VAR.: ALPHA
      .0      5.000 10.000 20.000
  INITIAL CONDITIONS:
  KS : .63400E-06
REYNOLDS NUMBER=891710000.0 TWALL=405.73 VBAR=0.0000 M/SQRN(RN)=0.0001

**SET **
--> 1,c
CONFIGURATION : 1
  11.00 FORWARD FUSELAGE BODY
  12.00 MID FUSELAGE BODY
  13.00 AFT FUSELAGE BODY
  14.00 POD OFF BODY
  121.00 WING SURFACE
      SYMBOL FLAP TYPE
      D1 1 SYMM
  211.00 VERTICAL SURFACE
      D2 ANTISYMM
  611.00 SLENDER BODY SLN BODY
  612.00 INTERF SHELL SHELL
** SET **

```

Figure 4-13. Modifying an Existing Run and Listing the Run Schedule and Configuration.

On figure 4-14, the entry "end" initiates the conversational mode of the SET command. The user is now given the opportunity to examine the aerodynamic model. Only questions that are pertinent to the Mach numbers of the run schedule are asked. Configuration verification must be performed prior to initial analysis in order to fix component parameters for viscous drag. Subsequent analysis using these components does not require model revalidation. The answer to the first question of figure 4-14 is then "no" instead of "yes".

```

      ** SET **
--> end
      CHECK CONFIGURATION MODELS: YES OR NO
--> yes
          ***** CONFIGURATION 1 LIFTING SOLUTION *****
                  ENTER "Y" FOR DISPLAYS , "N" TO SKIP
--> yes
      DISPLAY PANEL MODEL FOR CONFIGURATION 1
      YES OR NO :
--> yes

```

Figure 4-14. Ending SET and Initiating Analysis Model Verification.

The reference quantities and paneling, and the wing camber, thickness and twist are displayed on figures 4-15 through 4-18 respectively for review. The symbols on the curves in figures 4-16 through 4-18 mark the x/c location of the control points on the panels. The boundary conditions to be applied at each control point include camber and thickness (i.e., rate of change of these parameters) and may also be previewed by answering "yes" to the appropriate prompts as they are written on the screen. In the present case all reviewed data are accepted as satisfactory. On figure 4-19 the viscous-drag parameters for each component are entered by using carriage returns to accept the default values shown. The boundary layer transition point, the airfoil thickness correction factor of table 10 and the type of estimation (flat plate, axisymmetric body or airfoil) are specified. The default values are selected for full scale analysis here. For wind-tunnel evaluation, the transition point is usually fixed at the model grit line or natural transition point if known.

The input file for configuration 1 is now ready for background processing as discussed in section 5.

```

          ***** CONFIGURATION 1 VISCOUS DRAG PARAMETERS *****
          FORWARD FUSELAGE ENTER:  XTRANS/LENG, FLAT PLATE 1 * AXIS-BODY 2:
          DEFAULTS :  0.01, 2
--> <CR>
          WING                ENTER:  XTRANS/LENG, CK, FLAT PLATE 1 * AIRFOIL 2 :
          DEFAULTS:  0.010,1.20, 2
--> <CR>
          VERTICAL            ENTER:  XTRANS/LENG, CK, FLAT PLATE 1 * AIRFOIL 2 :
          DEFAULTS:  0.010,1.20, 2
--> <CR>
          ** OK **

```

Figure 4-19. Defining Viscous Drag Parameters.

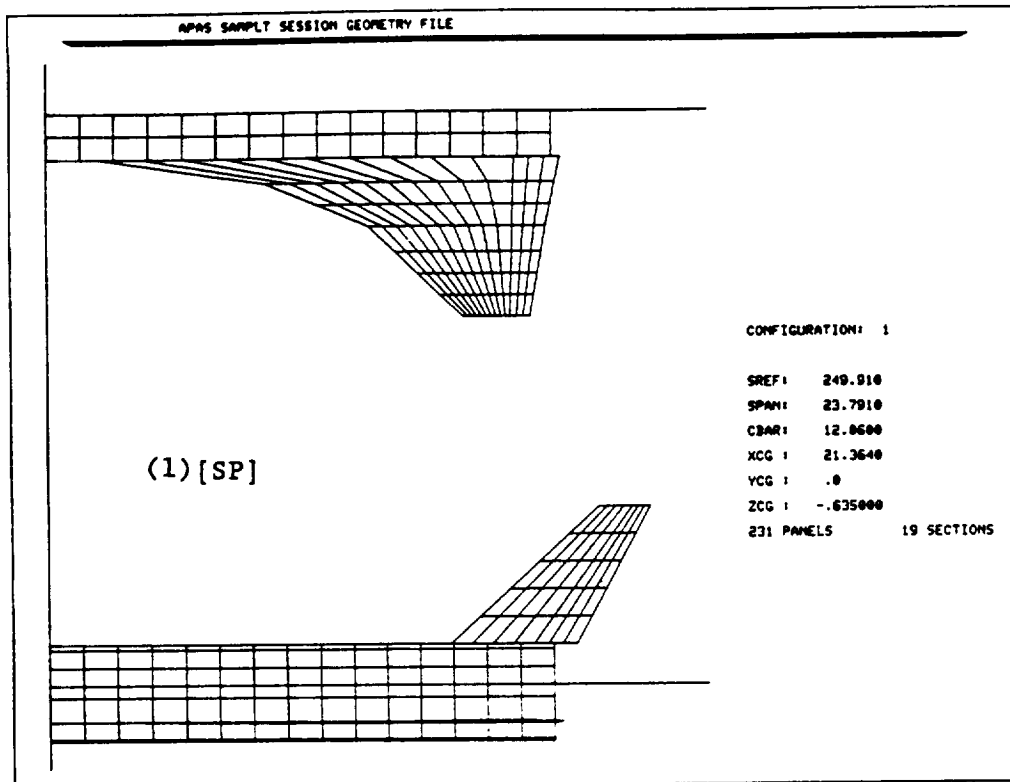


Figure 4-15. Subsonic-supersonic Analysis Paneling.

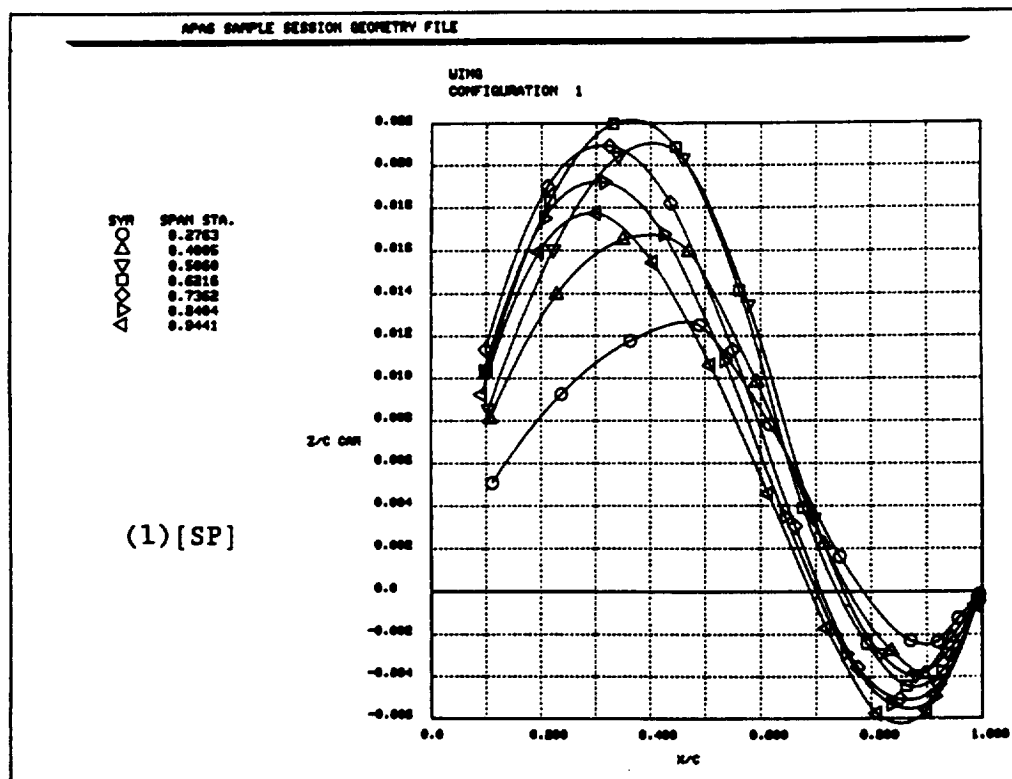


Figure 4-16. Wing Camber Distribution.

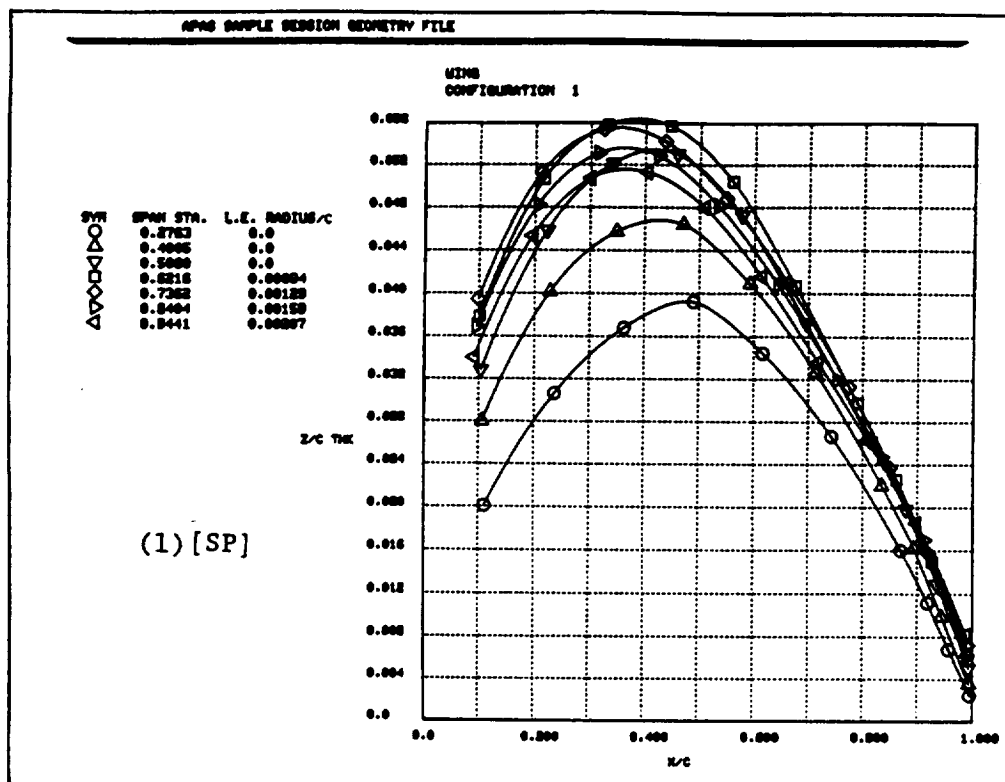


Figure 4-17. Wing Thickness Distribution.

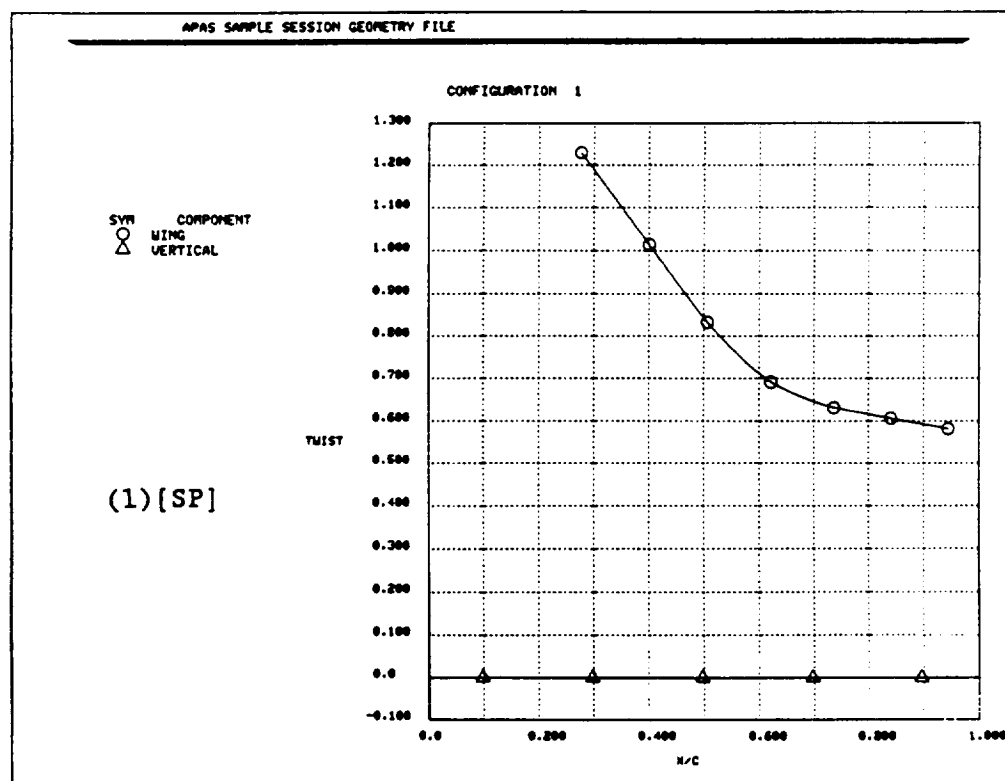


Figure 4-18. Surface Twist Distribution.

Hypersonic Configuration:

The same configuration is commonly used for both subsonic-supersonic and hypersonic analysis. In the present case however, a body flap can only be simulated for the latter case. A second configuration which includes this component is thus attached to the local as shown on figure 4-20.

+++ file,1	COMPN	NAME	TYPE	SYMM
	11.00	FORWARD FUSELAGE	1	2
	12.00	MID FUSELAGE	1	2
	13.00	AFT FUSELAGE	1	2
	14.00	POD	2	2
	121.00	WING	4	2
	211.00	VERTICAL	3	1
	400.00	BODY FLAP	1	2

OK

Figure 4-20. Hypersonic Configuration.

A run schedule is created in a similar way to the subsonic-supersonic example. Mach number of 10.0 is selected and automatically ($M > 4$) flags the run as hypersonic. A sand grain height is not required. The HABP analysis options menu (see below) is next and user responds as desired.

```
*****
*
*          **** HABP ANALYSIS OPTION MENU ****
*
* 0 - ACCEPT DEFAULT OPTIONS/ELSE: COMPLETELY RESET
* 1 - DO NOT INCLUDE COMPONENT SHIELDING EFFECTS
*      (DEFAULT: INCLUDE COMPONENT SHIELDING)
* 2 - SET MODEL SCALE
*      DEFAULT: MODEL SCALE - 1.0 IS FOR INPUT GEOMETRY)
* 3 - DO NOT INCLUDE SKIN FRICTION EFFECTS IN ANALYSIS
*      (DEFAULT: INCLUDE SKIN FRICTION EFFECTS)
* 4 - DO NOT ADD HEMISPHERICAL NOSE TO BODY PANELS
*      (DEFAULT: ADD HEMISPHERICAL NOSE CAP BETWEEN 1ST AND
*              2ND INPUT GEOMETRY SECTIONS IF INPUT BODY
*              NOSE HALF CONE ANGLE IS GREATER THAN 30 DEG)
*
*          EG: 1 4
*****
```


APAS next interrogates the user concerning hypersonic panel algorithm assignments and aerodynamic model acceptance. The response must be affirmative since this is the initial examination for configuration 2.

Figure 4-21 indicates the analysis method selection for the fuselage and pod components. Starting with the nose, the "1" response to the first question supplies a list of the available compression analysis methods. The user selects the default. The associated Newtonian correlation factor, k, is then requested and the default value of 1.8* is accepted.

```

FORWARD FUSELAGE NOSE          :
RECOMMENDED IMPACT METHOD:  MODIFIED NEWTONIAN
ENTER :  NUMBER :  OF DIFFERENT METHOD
        RETURN :  FOR RECOMMENDED METHOD
        L      :  TO LIST METHODS

--> 1

METHODS FOR IMPACT ANALYSIS:

    1 :  MODIFIED NEWTONIAN
    2 :  MODIFIED NEWTONIAN  +PRANDTL-MEYER
    3 :  TANGENT WEDGE
    4 :  TANGENT WEDGE EMP.
    5 :  TANGENT CONE EMP
    6 :  OSU BLUNT-BODY EMP.
    7 :  VAN DYKE UNIFIED METHOD
    8 :  BLUNT BODY SKIN FRICTION
    9 :  SHOCK EXPANSION METHOD
   10 :  FREE MOLECULAR FLOW
   11 :  INPUT PRESSURE COEF.
   12 :  HANKEY FLAT-SURFACE EMP.
   13 :  DELTA WING EMP.
   14 :  DAHLEM-BUCK EMP.
   15 :  BLAST-WAVE PRESSURE INCREMENTS
   16 :  MODIFIED TANGENT CONE
ENTER ANALYSIS METHOD NUMBER:

--> 1

IMPACT ANALYSIS METHOD: MODIFIED NEWTONIAN
ENTER VALUE FOR K (DEFAULT: 1.8000 )
(-1.0 WILL  PROVIDE STAGNATION K    )

--> <CR>

FORWARD FUSELAGE NOSE          :
RECOMMENDED SHADOW METHOD:  PRANDTL-MEYER EMP.
ENTER :  NUMBER :  OF DIFFERENT METHOD
        RETURN :  FOR RECOMMENDED METHOD
        L      :  TO LIST METHODS

--> 1

```

Figure 4-21. Hypersonic Analysis Methods for the Fuselage and Pod.

METHODS FOR SHADOW ANALYSIS:

- 1 : NEWTONIAN
- 2 : MODIFIED NEWTONIAN +PRANDTL-MEYER
- 3 : PRANDTL-MEYER EMP.
- 4 : OSU BLUNT-BODY EMP.
- 5 : VAN DYKE UNIFIED METHOD
- 6 : HIGH MACH NUMBER BASE PRESSURE
- 7 : SHOCK EXPANSION METHOD
- 8 : INPUT PRESSURE COEF.
- 9 : FREE MOLECULAR FLOW

ENTER ANALYSIS METHOD NUMBER:

→→→ 3

ENTER VALUE OF Q/QINF (DEFAULT: 1.000) :

→→→ <CR>

FORWARD FUSELAGE BODY :
 RECOMMENDED SHADOW METHOD: TANGENT CONE EMP.
 ENTER : NUMBER : OF DIFFERENT METHOD
 RETURN : FOR RECOMMENDED METHOD
 L : TO LIST METHODS

→→→ <CR>

FORWARD FUSELAGE BODY :
 RECOMMENDED SHADOW METHOD: PRANDTL-MEYER EMP.
 ENTER : NUMBER : OF DIFFERENT METHOD
 RETURN : FOR RECOMMENDED METHOD
 L : TO LIST METHODS

→→→ <CR>

ENTER VALUE OF Q/QINF (DEFAULT: 1.000) :

→→→ <CR>

MID FUSELAGE BODY
 RECOMMENDED SHADOW METHOD: TANGENT CONE EMP.
 ENTER : NUMBER : OF DIFFERENT METHOD
 RETURN : FOR RECOMMENDED METHOD
 L : TO LIST METHODS

→→→ <CR>

MID FUSELAGE BODY :
 RECOMMENDED SHADOW METHOD: PRANDTL-MEYER EMP.
 ENTER : NUMBER : OF DIFFERENT METHOD
 RETURN : FOR RECOMMENDED METHOD
 L : TO LIST METHODS

→→→ <CR>

ENTER VALUE OF Q/QINF (DEFAULT: 1.000) :

→→→ <CR>

AFT FUSELAGE BODY
 RECOMMENDED SHADOW METHOD: TANGENT CONE EMP.
 ENTER : NUMBER : OF DIFFERENT METHOD
 RETURN : FOR RECOMMENDED METHOD
 L : TO LIST METHODS

→→→ <CR>

Figure 4-21 (cont'd). Hypersonic Analysis Methods for the Fuselage and Pod.

```

AFT FUSELAGE BODY
RECOMMENDED SHADOW METHOD:  PRANDTL-MEYER EMP.
ENTER   : NUMBER   :   OF DIFFERENT METHOD
          RETURN   :   FOR RECOMMENDED METHOD
          L        :   TO LIST METHODS
---> <CR>
ENTER VALUE OF Q/QINF (DEFAULT:  1.000)  :
---> <CR>
AFT FUSELAGE          BLUNT END      :
RECOMMENDED SHADOW METHOD:  MODIFIED NEWTONIAN
ENTER   : NUMBER   :   OF DIFFERENT METHOD
          RETURN   :   FOR RECOMMENDED METHOD
          L        :   TO LIST METHODS
---> <CR>
IMPACT ANALYSIS METHOD: MODIFIED NEWTONIAN
ENTER VALUE FOR K (DEFAULT:  1.8000  )
(-1.0 WILL  PROVIDE STAGNATION K      )
---> <CR>
AFT FUSELAGE          BLUNT END      :
RECOMMENDED SHADOW METHOD:  HIGH MACH NUMBER BASE PRESSURE
ENTER   : NUMBER   :   OF DIFFERENT METHOD
          RETURN   :   FOR RECOMMENDED METHOD
          L        :   TO LIST METHODS
---> <CR>
ENTER VALUE OF Q/QINF (DEFAULT:  1.000)  :
---> <CR>
POD                   BODY           :
RECOMMENDED IMPACT METHOD:  TANGENT CONE EMP.
ENTER   : NUMBER   :   OF DIFFERENT METHOD
          RETURN   :   FOR RECOMMENDED METHOD
          L        :   TO LIST METHODS
---> <CR>
POD                   BODY           :
RECOMMENDED IMPACT METHOD:  PRANDTL-MEYER EMP.
ENTER   : NUMBER   :   OF DIFFERENT METHOD
          RETURN   :   FOR RECOMMENDED METHOD
          L        :   TO LIST METHODS
---> <CR>
ENTER VALUE OF Q/QINF (DEFAULT:  1.000)  :
---> <CR>
POD                   BLUNT END      :
RECOMMENDED SHADOW METHOD:  MODIFIED NEWTONIAN
ENTER   : NUMBER   :   OF DIFFERENT METHOD
          RETURN   :   FOR RECOMMENDED METHOD
          L        :   TO LIST METHODS
---> <CR>
IMPACT ANALYSIS METHOD: MODIFIED NEWTONIAN
ENTER VALUE FOR K (DEFAULT:  1.8000  )
(-1.0 WILL  PROVIDE STAGNATION K      )
---> <CR>

```

Figure 4-21 (cont'd). Hypersonic Analysis Methods for the Fuselage and Pod.

```

POD                BLUNT END      :
RECOMMENDED SHADOW METHOD:  HIGH MACH NUMBER BASE PRESSURE
ENTER   : NUMBER   :  OF DIFFERENT METHOD
          RETURN   :  FOR RECOMMENDED METHOD
          L        :  TO LIST METHODS
→→→ <CR>
      ENTER VALUE OF Q/QINF (DEFAULT:  1.000)  :
→→→ <CR>

```

Figure 4-21. Hypersonic Analysis Methods for the Fuselage and Pod.

Again, using the "1" response for the expansion analysis, a list of available shadow methods is displayed. The empirical Prandtl-Meyer expansion default is accepted. There are no other input parameters required for this method. The default value of 1.0 is selected for the ratio of local to free stream dynamic pressure and the setup goes on the the main part of the forward fuselage.

In the remainder of the panel algorithm assignments shown on figures 4-21 and 4-22, each body and surface is broken down, and analysis methods for each piece are selected. Note that since the fuselage components were consecutively numbered, a blunt base was not constructed until the aft fuselage and pod were set. The default methods for a surface with a flap are the ones shown here. If the SHKEP operand is used when setting up a given run they will be superseded by shock-expansion analysis at the time of analysis. After defining the hypersonic panel methods for each component, the user examines the finite element model, using the last two entries on figure 4-22. Typical views are presented on figures 4-23 and 4-24.

The input file for configuration 2 is now ready for background analysis.

```

WING                LEADING EDGE:
RECOMMENDED IMPACT METHOD:  MODIFIED NEWTONIAN
ENTER   : NUMBER   :  OF DIFFERENT METHOD
          RETURN   :  FOR RECOMMENDED METHOD
          L        :  TO LIST METHODS
+++ <CR>
IMPACT ANALYSIS METHOD:  MODIFIED NEWTONIAN
ENTER VALUE FOR K (DEFAULT:  1.8000  )
(-1.0 WILL PROVIDE STAGNATION K      )
+++ <CR>
WING                LEADING EDGE:
RECOMMENDED IMPACT METHOD:  PRANDTL-MEYER EMP.
ENTER   : NUMBER   :  OF DIFFERENT METHOD
          RETURN   :  FOR RECOMMENDED METHOD
          L        :  TO LIST METHODS
+++ <CR>
ENTER VALUE OF Q/QINF (DEFAULT:  1.000)  :
+++ <CR>
WING                SURFACE      :
RECOMMENDED IMPACT METHOD:  TANGENT WEDGE EMP.
ENTER   : NUMBER   :  OF DIFFERENT METHOD
          RETURN   :  FOR RECOMMENDED METHOD
          L        :  TO LIST METHODS
+++ <CR>
WING                SURFACE      :
RECOMMENDED SHADOW METHOD:  PRANDTL-MEYER EMP.
ENTER   : NUMBER   :  OF DIFFERENT METHOD
          RETURN   :  FOR RECOMMENDED METHOD
          L        :  TO LIST METHODS
+++ <CR>
ENTER VALUE OF Q/QINF (DEFAULT:  1.000)  :
+++ <CR>
WING                BLUNT T.E.   :
RECOMMENDED IMPACT METHOD:  MODIFIED NEWTONIAN
ENTER   : NUMBER   :  OF DIFFERENT METHOD
          RETURN   :  FOR RECOMMENDED METHOD
          L        :  TO LIST METHODS
+++ <CR>
IMPACT ANALYSIS METHOD:  MODIFIED NEWTONIAN
ENTER VALUE FOR K (DEFAULT:  1.8000  )
(-1.0 WILL PROVIDE STAGNATION K      )
+++ <CR>
WING                BLUNT T.E.   :
RECOMMENDED SHADOW METHOD:  HIGH MACH NUMBER BASE PRESSURE
ENTER   : NUMBER   :  OF DIFFERENT METHOD
          RETURN   :  FOR RECOMMENDED METHOD
          L        :  TO LIST METHODS
+++ <CR>
ENTER VALUE OF Q/QINF (DEFAULT:  1.000)  :
+++ <CR>

```

Figure 4-22. Hypersonic Methods for Wing, Vertical Tail and Body Flap.

```

VERTICAL          SURFACE      :
RECOMMENDED IMPACT METHOD: MODIFIED NEWTONIAN
ENTER   : NUMBER   : OF DIFFERENT METHOD
          RETURN   : FOR RECOMMENDED METHOD
          L        : TO LIST METHODS
--> <CR>
IMPACT ANALYSIS METHOD: MODIFIED NEWTONIAN
ENTER VALUE FOR K (DEFAULT: 1.8000 )
(-1.0 WILL PROVIDE STAGNATION K )
--> <CR>
BODY FLAP          SURFACE      :
RECOMMENDED IMPACT METHOD: TANGENT WEDGE EMP.
ENTER   : NUMBER   : OF DIFFERENT METHOD
          RETURN   : FOR RECOMMENDED METHOD
          L        : TO LIST METHODS
--> 4
BODY FLAP          SURFACE      :
RECOMMENDED SHADOW METHOD: PRANDTL-MEYER EMP.
ENTER   : NUMBER   : OF DIFFERENT METHOD
          RETURN   : FOR RECOMMENDED METHOD
          L        : TO LIST METHODS
--> 3
ENTER VALUE OF Q/QINF (DEFAULT: 1.000) :
--> <CR>
DO YOU WISH TO SEE CONFIGURATION 2
YES OR NO :
--> yes
INPUT YAW, PITCH, ROLL ANGLES FOR DISPLAY:
--> 60-30 30

```

Figure 4-22 (cont'd). Hypersonic Methods for Wing, Vertical Tail and Body Flap.

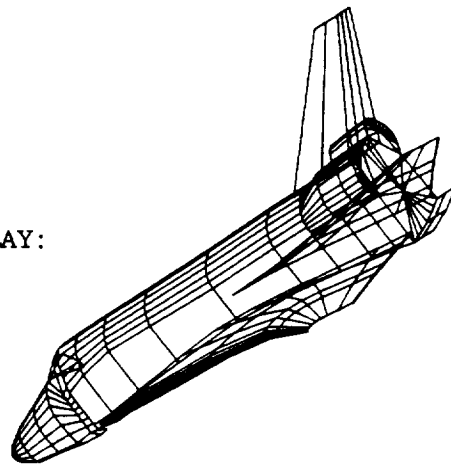
```

APAS SAMPLE SESSION GEOMETRY FILE

YAW  PITCH  ROLL
60.0 -30.0  30.0

* 1 VIEW *
* E END   *
* ENTER COMMAND:
--> 1
INPUT YAW,PITCH,ROLL ANGLES FOR DISPLAY:
--> 90 0 90

```



(1) [SP]

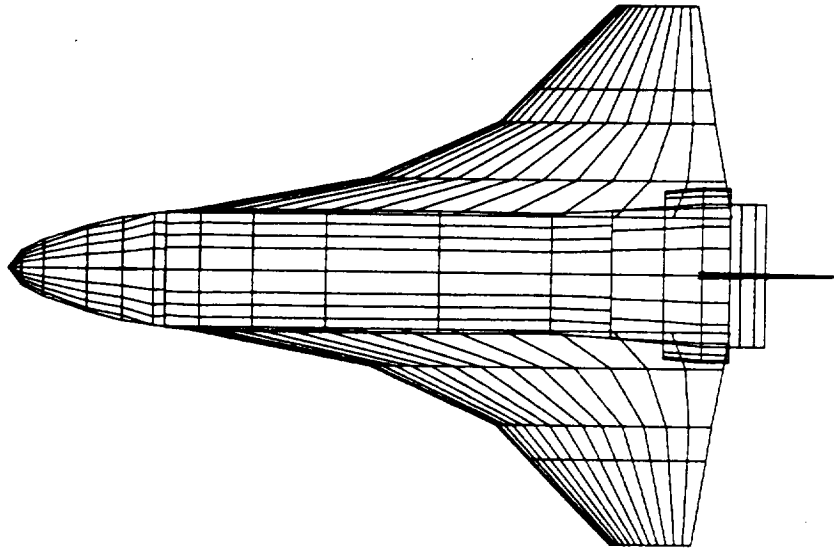
Figure 4-23. Orthographic Projection of the Hypersonic Geometry Model.

APAS SAMPLE SESSION GEOMETRY FILE

YAW	PITCH	ROLL
90.0	0.0	90.0

* 1 VIEW *
* E END *
* ENTER COMMAND:

→→→ e



(1) [SP]

Figure 4-24. Top View of the Hypersonic Geometry Model.

Section 5

ANALYSIS OUTPUT

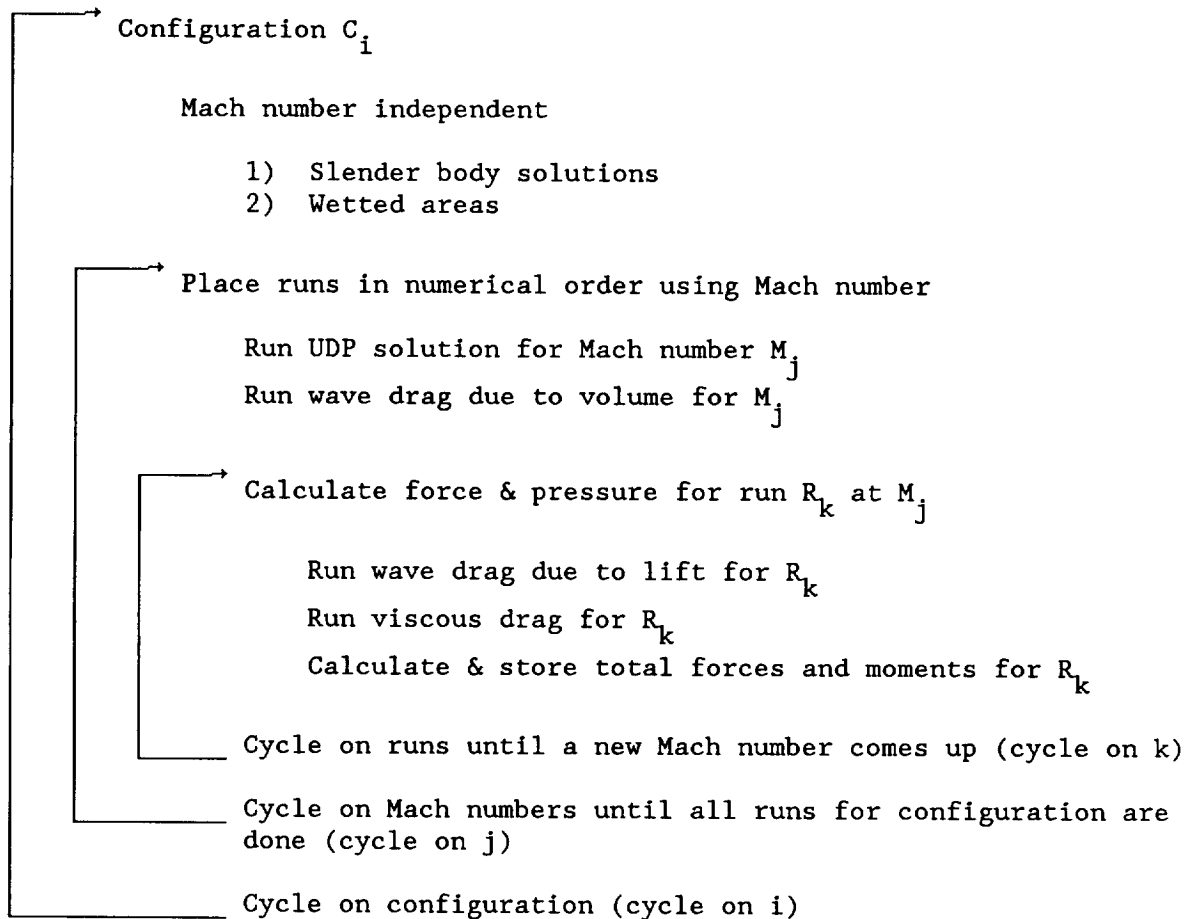
Foreground (interactive) analysis results are discussed in section 4 in order to correlate them with directives to prompts and will not be repeated.

Background analysis results are available in two forms: detailed print data and output file storage of forces, moments, and pressures of each specified vehicle condition for interactive display.

The most commonly used printed results are discussed initially. More specialized information which can be used to uncover problems is subsequently considered. The output display command PLOT, and its subcommands are then described to introduce the user to their capabilities. Sample sessions illustrating various PLOT subcommands is provided to familiarize the user with generating displays of the analysis results.

PRINT

APAS analysis is structured to minimize repetitive calculations. Processing and printout are in the same order and as follows.



A detailed output variable glossary is presented in appendix C for decoding printed results. Figure 5-1 presents slender body solution results. Each slender body of the configuration has similar output. A cursory examination of the force coefficients should be made to identify obvious problems such as negative lift, positive side force, etc.

A component summary of the configuration surface area and volume obtained from a cutting plane analysis is presented on figure 5-2. These results are similar to those from foreground analysis and will differ slightly from the contour integration skin friction results of figure 5-7.

General output of the subsonic-supersonic panel solution is shown in figure 5-3. The reference data should correspond to SET input data. The symmetry codes should be one (1) except for the centerline vertical and antisymmetric surfaces such as skewed wings which are zero (0). Surface lateral extent and the number of spanwise panels should be verified.

Users typically scan subsonic-supersonic analysis for the complete configuration forces and moments (figure 5-4). Unit solutions for symmetrical (longitudinal) characteristics are printed first followed by antisymmetrical (lateral-directional) results.

Supersonic wave drag due to volume is then printed (figure 5-5). These results should be the same as the WAVEDRAG command interactive analysis. The next three pages present the lifting wave drag for three angles of attack. Figure 5-6 present the results of one calculation.

The evaluation is then followed by the viscous-drag solution (figure 5-7). The results will be the same as those from the VISCOUS command interactive analysis.

Figure 5-8 presents a six component data summary of the subsonic-supersonic analysis as a function of angle of attack or sideslip. Results are presented for the aerodynamic characteristics with and without edge (leading and tip) vortex considerations. The drag results do not include friction or wave drag due to volume and correspond to zero (CD0), one hundred percent (CD100), or attainable suction (CDL) drag due to lift.

Typical hypersonic analysis results are presented on figures 5-9 through 5-12. Six component aerodynamic characteristics are evaluated in a component buildup format. An initial page, (figure 5-9) presents the breakdown of the configuration and the flap symbols (if any) applied to the control surfaces.

The analysis is processed component by component for each run. The output is similar to that used in the hypersonic arbitrary body program, reference 2. Surface area and volume characteristics and panel compression/expansion algorithms are presented for each component (figure 5-10) followed by its forces and moments (figure 5-11). Complete configuration characteristics are then summarized (figure 5-12). Note that the results are for air and the flap has been calculated without shock expansion algorithms. In the last two columns, C AF is skin friction and %LAMINAR indicates percent of vehicle surface area in laminar flow.

APAS SAMPLE SESSION GEOMETRY FILE

SREF (M2)	SPAN (M)	CBAR (M)	X-CG (M)	Y-CG (M)	Z-CG (M)
249.9100	23.7910	12.0600	21.3540	0.0	-0.6350

BC	DESC	CY	CL	CLL	CM	CN
1	AL=0	-0.00000	0.02825	-0.00000	0.05555	-0.00000
2	AL=1	0.00000	0.00792	0.00000	0.00535	0.00000
3	QB=1	-0.00000	0.79243	0.00000	-0.78205	-0.00001
4	BE=1	-0.00707	0.00000	0.00003	-0.00000	-0.00291
5	PB=1	-0.04479	0.00923	-0.00275	-0.00450	0.00176
6	RB=1	0.30131	-0.01009	0.01052	-0.00706	-0.22640

X	S/L ²	SPX	SFPX	WXL	CNB1	CNB2	SPPXR
0.000	0.00000	0.0	11.09628	0.00000	0.0	0.0	11.09628
0.510	0.00143	0.09538	4.73393	0.04349	-0.01259	0.00285	1.01427
1.527	0.00489	0.09778	-0.89088	0.07807	0.07807	-0.04246	-0.59902
2.286	0.00705	0.09231	-1.68680	0.09615	-0.05459	0.00381	0.10348
4.572	0.01417	0.11941	-0.02370	0.13441	-0.05852	0.00389	0.47133
6.323	0.02162	0.11941	-0.10122	0.15292	0.08098	0.00348	-0.89094
8.647	0.02631	0.04191	-1.64928	0.16600	0.07996	0.00222	-0.31245
17.595	0.02829	0.00653	0.87715	0.16643	0.00322	0.00030	0.00291
24.753	0.02967	0.01579	0.23818	0.16958	0.00391	0.00079	0.03410
25.768	0.03022	0.01719	1.04351	0.17212	-0.13447	0.00090	0.20076
26.542	0.03064	0.05716	1.44867	0.17434	-0.22401	0.00258	3.83406
27.947	0.03637	0.10831	1.07900	0.20365	-0.05327	0.00602	-0.98409
29.146	0.03978	0.06172	-0.32064	0.22971	0.13513	0.00476	-1.53435
30.538	0.04104	0.01357	-2.17424	0.24116	0.03887	0.00070	-0.66423
31.750	0.04105	-0.01285	0.04297	0.23471	-0.05333	-0.00164	0.09318

SLENDER BODY SOLUTION HAS BEEN CALCULATED - COMPUTATION TIME 13.938 SEC.

Figure 5-1. Slender Body Solution.

VISCOUS DRAG PROGRAM

APAS SAMPLE SESSION GEOMETRY FILE

NUMBER	COMPONENT	WETTED AREA (M2)	VOLUME (M3)
11.00	FORWARD FUSELAGE	75.68	73.79
12.00	MID FUSELAGE	341.42	555.09
13.00	AFT FUSELAGE	71.01	157.79
14.00	POD	52.04	40.79
121.00	WING	397.27	157.61
211.00	VERTICAL	76.92	5.10
	TOTAL:	1014.34	990.16

Figure 5-2. Viscous Solution Wetted Area and Volume Summary.

UNIFIED DISTRIBUTED PANEL PROGRAM
APAS SAMPLE SESSION GEOMETRY FILE

SREF (M2)	SPAN (M)	CBAR (M)	X-CG (M)	Y-CG (M)	Z-CG (M)
249.9100	23.7910	12.0600	21.3540	0.0	-0.6350

COMPONENT NAME	TYPE	SYMMETRY			SPANWISE ACTIVE VORTEX		
		INDICATOR	SEMI-SPAN	INCIDENCE	PANELS	IND	IND
INTERF SHELL	5	ON	9.9575	0.0	7	ON	OFF
WING	4	ON	11.5764	0.0	7	ON	ON
VERTICAL	3	OFF	8.0299	0.0	5	ON	OFF

Figure 5-3. Lifting Surface Solution Header Page.

COMPONENT 2 WING

ETA	CHORD	TWIST(DEG)	CN	CN*C/CAVG	CL*C/CAVG	X/C C.P.
0.27625	20.46275	0.0	0.02702	0.05122	0.05105	0.53887
0.40049	14.14536	0.0	0.03765	0.04934	0.04934	0.45133
0.50597	11.13342	0.0	0.04689	0.04837	0.04837	0.41852
0.62157	8.72438	0.0	0.05752	0.04649	0.04643	0.38419
0.73625	7.16045	0.0	0.06608	0.04384	0.04383	0.38441
0.84042	5.74060	0.0	0.07206	0.03832	0.03831	0.36881
0.94414	4.32683	0.0	0.06552	0.02626	0.02626	0.29645

NORMAL/SIDE	LIFT	SIDE	ROLL	PITCH	YAW
0.01723	0.03443	0.0	0.0	-0.00995	0.0

COMPONENT 3 VERTICAL CAVG = 31.12254

ETA	CHORD	TWIST(DEG)	CN	CN*C/CAVG	CL*C/CAVG	X/C C.P.
0.09789	6.43027	0.0	0.00000	0.00000	0.0	0.0
0.29759	5.62477	0.0	-0.00000	-0.00000	0.0	0.0
0.49718	4.81967	0.0	-0.00000	-0.00000	0.0	0.0
0.69661	4.01526	0.0	-0.00000	-0.00000	0.0	0.0
0.89574	3.21202	0.0	-0.00000	-0.00000	0.0	0.0

NORMAL/SIDE	LIFT	SIDE	ROLL	PITCH	YAW
-0.00000	0.0	0.00000	0.00000	0.0	-0.00000

TOTAL FORCES AND MOMENTS FOR THE COMPLETE CONFIGURATION

FORCE		MOMENT			CENTER OF PRESSURE X STATION
LIFT	SIDE	ROLL	PITCH	YAW	
0.04743	0.00000	0.00000	-0.00000	0.00000	22.85327

Figure 5-4. Subsonic-supersonic Panel Solution Forces and Moments.

WAVE DRAG PROGRAM

APAS SAMPLE SESSION GEOMETRY FILE

MACH=	1.600	VOLUME DRAG	
NO.	THETA	D/Q	
1	-90.000	32.8766	
2	-82.500	22.4307	
3	-75.000	14.6326	
4	-67.500	12.1368	
5	-60.000	12.4817	
6	-52.500	13.3022	
7	-45.000	14.7906	
8	-37.500	18.6805	
9	-30.000	17.8035	
10	-22.500	17.3735	
11	-15.000	18.8717	
12	-7.500	18.9401	
13	0.0	20.1280	
14	7.500	20.9426	
15	15.000	24.0547	
16	22.500	27.3976	
17	30.000	31.1302	
18	37.500	29.2453	
19	45.000	37.0710	
20	52.500	37.4960	
21	60.000	30.9462	
22	67.500	32.7350	
23	75.000	37.5587	
24	82.500	42.7536	
25	90.000	48.0824	
** TOTAL WAVE DRAG		24.6787	
** TOTAL COEFFICIENT		0.098750	

Figure 5-5. Volume Wave Drag Solution.

WAVE DRAG PROGRAM

APAS SAMPLE SESSION GEOMETRY FILE

MACH= 1.600		VOLUME DRAG	
NO.	THETA		D/Q
1	-90.000		35.8427
2	-82.500		29.6606
3	-75.000		23.8080
4	-67.500		19.4547
5	-60.000		16.4867
6	-52.500		14.4289
7	-45.000		13.9046
8	-37.500		17.2065
9	-30.000		15.4639
10	-22.500		15.1732
11	-15.000		17.2207
12	-7.500		17.8595
13	0.0		19.9613
14	7.500		21.9959
15	15.000		26.6143
16	22.500		31.5220
17	30.000		36.9408
18	37.500		38.8132
19	45.000		48.1823
20	52.500		48.3128
21	60.000		42.9049
22	67.500		49.1249
23	75.000		59.0378
24	82.500		73.4263
25	90.000		93.9657
** TOTAL WAVE DRAG		31.6825 VOLUME + LIFT	
** TOTAL COEFFICIENT		0.126776	

Figure 5-6. Lifting Wave Drag Solution.

VISCOUS DRAG PROGRAM

APAS SAMPLE SESSION GEOMETRY FILE									
MACH: 1.600 ALT: 3045.	M PRESS: 69683.687	NT/M2	TEMP: 268.340	K	SREF: 249.910	M2	KS: 0.00000634	M	
COMPONENT	WET SLRF	CCMP	FF	X/L	REYNOLDS	CDF	CDF	CDF	
	AREA M2	LENGTH M		TRANS.	NO.	SMOOTH	ROUGH	USED	
FORWARD FUSELAGE	540.1	31.750	1.144	0.010	8.91710E+08	0.00314	0.00292	0.00314	
WING	126.4	20.100	1.100	0.010	5.64510E+08	0.00075	0.00070	0.00075	
WING	123.6	12.573	1.129	0.010	3.53129E+08	0.00080	0.00075	0.00080	
WING	50.02	8.695	1.146	0.010	2.44203E+08	0.00035	0.00033	0.00035	
WING	83.04	5.707	1.137	0.010	1.60281E+08	0.00060	0.00057	0.00060	
VERTICAL	77.22	4.808	1.048	0.010	1.35044E+08	0.00053	0.00050	0.00053	

** TOTAL WET SURFACE AREA = 1000.45 M2									
** TOTAL SKIN FRICTION DRAG = 0.00618									
** TOTAL VEHICLE BASE DRAG = 0.04427									

Figure 5-7. Viscous Drag Solution.

UNIFIED DISTRIBUTED PANEL PROGRAM
APAS SAMPLE SESSION GEOMETRY FILE

SCHEDULE FOR RUN 1

MACH	CT	P	Q	R	D1	D2				
1.60	0.0	0.0	0.0	0.0	10.00	0.0				
ALPHA	BETA	LIFT	SIDE	ROLL	PITCH	YAW				
0.0	0.0	0.10497	0.0	0.0	0.00746	0.0	CD0:	0.013302	CD100:	0.029840 LINEAR
0.0	0.0	0.10497	0.0	0.0	0.00746	0.0	CDL:	0.029840	SUCTION:	1.000 W/LE VTX
0.0	0.0	0.10543	0.0	0.0	0.00718	0.0	CDL:	0.029866	SUCTION:	0.235 W/TIP VTX
5.00	0.0	0.34212	0.0	0.0	-0.02203	0.0	CD0:	0.042796	CD100:	0.046496 LINEAR
5.00	0.0	0.34212	0.0	0.0	-0.02203	0.0	CDL:	0.046496	SUCTION:	1.000 W/LE VTX
5.00	0.0	0.34634	0.0	0.00002	-0.02483	0.0	CDL:	0.047179	SUCTION:	0.058 W/TIP VTX
10.00	0.0	0.57927	0.0	0.0	-0.05151	0.0	CD0:	0.110192	CD100:	0.092922 LINEAR
10.00	0.0	0.57927	0.0	0.0	-0.05151	0.0	CDL:	0.092923	SUCTION:	0.994 W/LE VTX
10.00	0.0	0.59400	0.0	0.00009	-0.06103	0.0	CDL:	0.096490	SUCTION:	0.031 W/TIP VTX
20.00	0.0	1.05356	0.0	0.0	-0.11047	0.0	CD0:	0.358332	CD100:	0.275087 LINEAR
20.00	0.0	1.05375	0.0	0.0	-0.11038	0.0	CDL:	0.275260	SUCTION:	0.601 W/LE VTX
20.00	0.0	1.10786	0.0	0.00049	-0.14468	0.0	CDL:	0.298494	SUCTION:	0.011 W/TIP VTX

Figure 5-8. Subsonic-supersonic Analysis Summary.

HYPERSONIC ARBITRARY-BODY PROGRAM, MARK III MOD 3

APAS SAMPLE SESSION GEOMETRY FILE
CONFIGURATION: 2

COMPONENT	NAME	SYMBOL	FLAP	TYPE
11.00	FORWARD FUSELAGE			
12.00	MID FUSELAGE			
13.00	AFT FUSELAGE			
14.00	POD			
121.00	WING			
211.00	VERTICAL	D1	1	SYMM
400.00	BODY FLAP	D2	2	ANTISYMM

Figure 5-9. Hypersonic Analysis Configuration.

HYPERSONIC ARBITRARY-BODY PROGRAM, MARK III MOD 3
 RUN 3

APAS SAMPLE SESSION GEOMETRY FILE

FORWARD FUSELAGE BODY NOSE			TOTAL AREA OF INPUT ELEMENTS		M2 =	1.124	TOTAL NUMBER OF ELEMENTS =		40
			TOTAL VOLUME OF INPUT ELEMENTS		M3 =	0.218			
IMPACT: 1	ISHAD: 3	IMPACT: 0	ISHADI: 0	CPSTAG: 1.20	QQINF: 1.00	ENPN: 0.0	ETAC: 1.00		
*****			*****		*****				
FORWARD FUSELAGE MAIN BODY, SEGMENT: 3			TOTAL AREA OF INPUT ELEMENTS		M2 =	11.513	TOTAL NUMBER OF ELEMENTS =		10
			TOTAL VOLUME OF INPUT ELEMENTS		M3 =	3.977			
IMPACT: 5	ISHAD: 3	IMPACT: 0	ISHADI: 0	CPSTAG: 1.20	QQINF: 1.00	ENPN: 0.0	ETAC: 1.00		
*****			*****		*****				
FORWARD FUSELAGE MAIN BODY, SEGMENT: 2			TOTAL AREA OF INPUT ELEMENTS		M2 =	23.493	TOTAL NUMBER OF ELEMENTS =		35
			TOTAL VOLUME OF INPUT ELEMENTS		M3 =	29.939			
IMPACT: 5	ISHAD: 3	IMPACT: 0	ISHADI: 0	CPSTAG: 1.20	QQINF: 1.00	ENPN: 0.0	ETAC: 1.00		
*****			*****		*****				
FORWARD FUSELAGE MAIN BODY, SEGMENT: 1			TOTAL AREA OF INPUT ELEMENTS		M2 =	4.349	TOTAL NUMBER OF ELEMENTS =		4
			TOTAL VOLUME OF INPUT ELEMENTS		M3 =	2.381			
IMPACT: 5	ISHAD: 3	IMPACT: 0	ISHADI: 0	CPSTAG: 1.20	QQINF: 1.00	ENPN: 0.0	ETAC: 1.00		
*****			*****		*****				

Figure 5-10. Hypersonic Analysis Panel Summary.

APAS SAMPLE SESSION GEOMETRY FILE

FORWARD FUSELAGE AIR

MACH =	10.000	VEL =	3366.9	M/SEC	RE/M =	0.19887E+08
ALT =	3049. M					
P =	0.0	Q =	0.0	R =	0.0	
D1 =	0.0	D2 =	0.0	D3 =	0.0	
SREF =	249.91	M2 SPAN =	23.79	M MAC =	12.06	M
X CG =	21.35	M Y CG =	0.0	M Z CG =	-0.63	M

FORCE DATA

ALPHA	C D	C L	C A	C Y	C N		
BETA	L/D	C M	C LL	C LN	C F	C AF	%LAMINAR
0.0	0.03425	-0.02732	0.03425	0.0	-0.02732		
0.0	-0.79761	-0.03521	0.0	0.0	0.0	0.001193	0.0
5.0	0.02862	-0.01561	0.02987	0.0	-0.01306		
0.0	-0.54560	-0.01532	0.0	0.0	0.0	0.001186	0.0
10.0	0.02622	-0.00264	0.02628	0.0	0.00195		
0.0	-0.10087	0.00559	0.0	0.0	0.0	0.001179	0.0
20.0	0.03169	0.02321	0.02184	0.0	0.03265		
0.0	0.73233	0.04830	0.0	0.0	0.0	0.001052	0.0

Figure 5-11. Hypersonic Analysis Component Summary.

HYPERSONIC ARBITRARY-BODY PROGRAM, MARK III MOD 3
 RUN 3

APAS SAMPLE SESSION GEOMETRY FILE

TOTAL MOMENTS AND FORCES FOR COMPLETE CONFIGURATION AIR
 FLAP DATA DOES NOT INCLUDE SHOCK EXPANSION ALGORITHMS

MACH - 10.000 VEL - 3366.9 M/SEC RE/M - 0.19887E+08
 ALT - 3049.M
 P - 0.0 Q - 0.0 R - 0.0
 D1 - 0.0 D2 - 0.0 D3 - 0.0
 S REF - 249.91 M2 SPAN - 23.79 M MAC - 12.06 M
 X CG - 21.35 M Y CG - 0.0 M Z CG - -0.63 M

FORCE DATA

ALPHA	C D	C L	C A	C Y	C N		
BETA	L/D	C M	C LL	C LN	C F	C AF	%LAMINAR
0.0	0.06270	-0.04588	0.06270	-0.00000	-0.04588		
0.0	-0.73173	-0.06247	-0.00000	0.00000	0.0	0.007234	0.0
5.0	0.05780	0.02464	0.05543	-0.00000	0.02958		
0.0	0.42628	-0.00093	-0.00000	0.00000	0.0	0.007945	0.0
10.0	0.07259	0.12054	0.05055	-0.00000	0.13132		
0.0	1.66063	0.00449	-0.00000	0.00000	0.0	0.009664	0.0
20.0	0.19409	0.39557	0.04710	-0.00000	0.43810		
0.0	2.03804	0.01625	-0.00000	0.00000	0.0	0.013397	0.0

- NOTE: 1) C_L , C_D ARE IN STABILITY AXIS SYSTEM (NORMAL SYSTEM DEFINITION)
 2) OTHER COEFFICIENTS ARE IN BODY REFERENCE COORDINATE SYSTEM
 3) C_Y (SIDE), C_M (PITCHING) INVARIANT TO (α, β) TRANSFORMATION
 4) C_{LN} (YAWING), C_{LL} (ROLLING) MOMENT ARE NOT INVARIANT

Figure 5-12. Hypersonic Analysis Total Configuration Summary.

DISPLAY

Interactive plotting of aerodynamic results is accomplished using the PLOT command of section six.

There are thirty-seven parameters (table 5) available for plotting at each (α, β) combination (analysis point) for subsonic-supersonic runs. The available plotting parameters for hypersonic runs are indicated by an * in front of the location column in table 5. The reduced number of plotting parameters for hypersonic runs occurs because: (1) the parameter(s) are meaningless relative to impact theory (for example; suction, linear etc.); or (2) the large (unrestricted) number of panels exceeds the storage allocations (as for cp data).

The LIST subcommand enables the user to review all the analysis runs in the output file and initial conditions for each run.

The SET subcommand of PLOT minimizes keyboard entries required by presetting up to twelve commonly used plot lines. User inputs at the time of display generation will override entries of the set list. Each of the aerodynamic variables can be displayed as a function of angle of attack or sideslip. Multiple runs can be combined to display results as a function of Mach number or one of the flap-deflection angles (D1 to D6) where applicable using the RUN operand of the PLOT subcommand of PLOT. Run lists are also used to simultaneously display more than one run on a single plot for comparison. The RUNM operand permits identification of run list subsets.

An existing run list applies to the current and all subsequent displays until modified by the user. A Mach list applies only to the current display and is replaced by the prior run list for the next display. Initial conditions for each grid should be specified for a Mach list.

There are three display formats and five grids available for plotting aerodynamic results. They are illustrated in figures 5-13 through 5-15. Grid positions do not have to be specified in order on a PLOT or SET list; however grids cannot be skipped, i.e., if grid 2 is filled then grid 1 must also have a plot specified or an error will result. Form 1 contains three narrow grids, figure 5-13, and is typically used to display slope data as a function of Mach number. Form 2 is useful for displaying a force or moment coefficient as a function of the run variable (V_r) on grid 2 and the slope or value at $V_r = 0$ as a function of Mach number on grid 1. Form 3, figure 5-15, is commonly used to display force and moment coefficients as a function of the run variable.

Table 5. Aerodynamic Parameter Storage.

<u>Location</u>	<u>Symbol</u>	<u>Description</u>
1	TT	Free Stream Total Temperature
2	PT	Free Stream Total Pressure
3	PFS	Free Stream Static Pressure
4	q	Dynamic Pressure, $1/2 \rho V^2$
5	RN	Reynolds Number/L
6	M	Mach Number
7	CN	Normal-Force Coefficient [HABP only]
8	CA	Axial-Force Coefficient [HABP only]
9	CL	Lift Coefficient Includes LE Vortex
10	CM	Pitching-Moment Coefficient Effect[If Present]
11	CD	Total-Drag Coefficient
12	CDP	Viscous-Drag Coefficient (Shear+ δ^*)
13	CDM	Wave-Drag Coefficient [UDP only]
14	CDOZERO	Zero Suction Drag Coefficient [UDP only]
15	CD100	100% Suction Drag Coefficient [UDP only]
16	CY	Side-Force Coefficient Includes LE
17	CN	Yawing-Moment Coefficient Vortex Effects
18	CR	Rolling-Moment Coefficient [If Present]
19	CLA	dCL/d α , per degree (lift) .
20	CMA	dCM/d α , per degree(pitch) .
21	CYB	dCY/d β , per degree (side) .
22	CNB	dCN/d β , per degree (yaw) .
23	CRB	dCR/d β , per degree (roll) .
24	ALPHA	Angle of Attack, degrees
25	BETA	Angle of Sideslip, degrees
26	DCMDCL	Pitch Stability, dCM/dCL
27	LOD	Lift Over Drag, CL/CD
28	Analysis	Analysis Indicator, [UDP=1.0, HABP=2.0]
29	CLLIN	CL (lift) Linear Results Only
30	CMLIN	CM (pitch) [Excludes LE Vortex]
31	CYLIN	CY (side) .
32	CNLIN	CN (yaw) .
33	CRLIN	CR (roll) .
34	CLALIN	dCL/d α , per degree .
35	CMALIN	dCM/d α , per degree .
36	CYBLIN	dCY/d β , per degree .
37	CNBLIN	dCN/d β , per degree .
38	CRBLIN	dCR/d β , per degree .
39	CDL	Drag-Due-To-Lift Coefficient [UDP only]
40	CDBASE	Base-Drag Coefficient [UDP only]
41	CLBASIC	CL for basic load [UDP only]
42	CMBASIC	CM for basic load [UDP only]
43	CYBASIC	CY for basic load [UDP only]
44	CNBASIC	CN for basic load [UDP only]
45	CRBASIC	CR for basic load [UDP only]
46	OPEN	Unused Data Location
47	OPEN	Unused Data Location
48	OPEN	Unused Data Location
49	OPEN	Unused Data Location
50	NPANELS	Number of Panels in Configuration

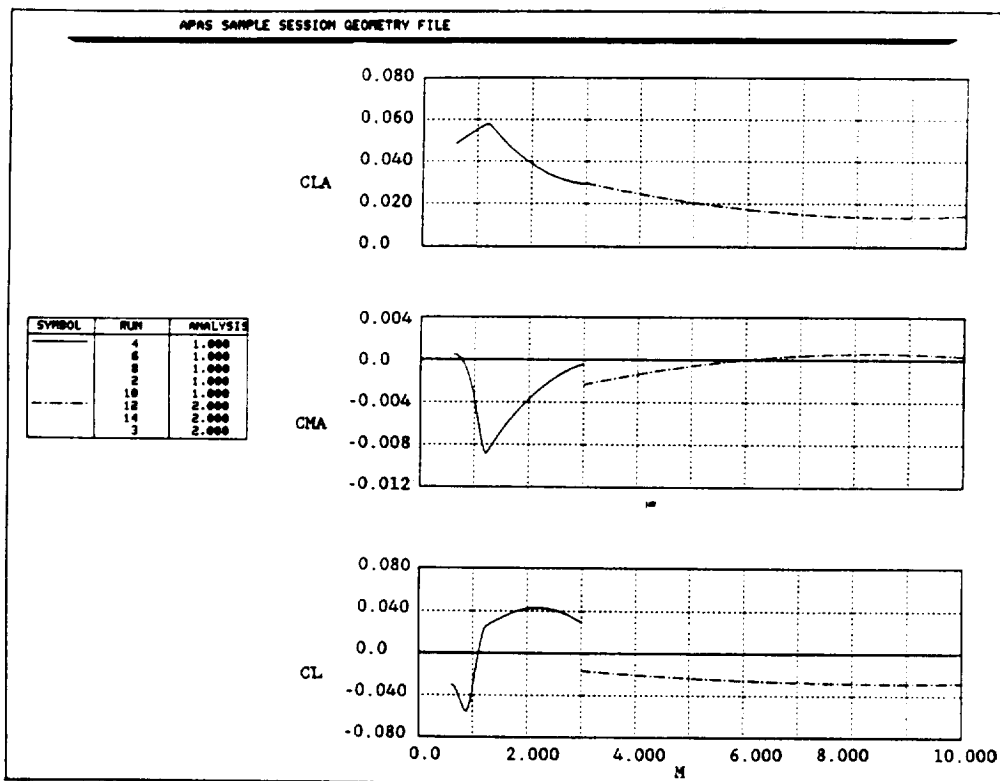


Figure 5-13. PLOT Form 1 Display.

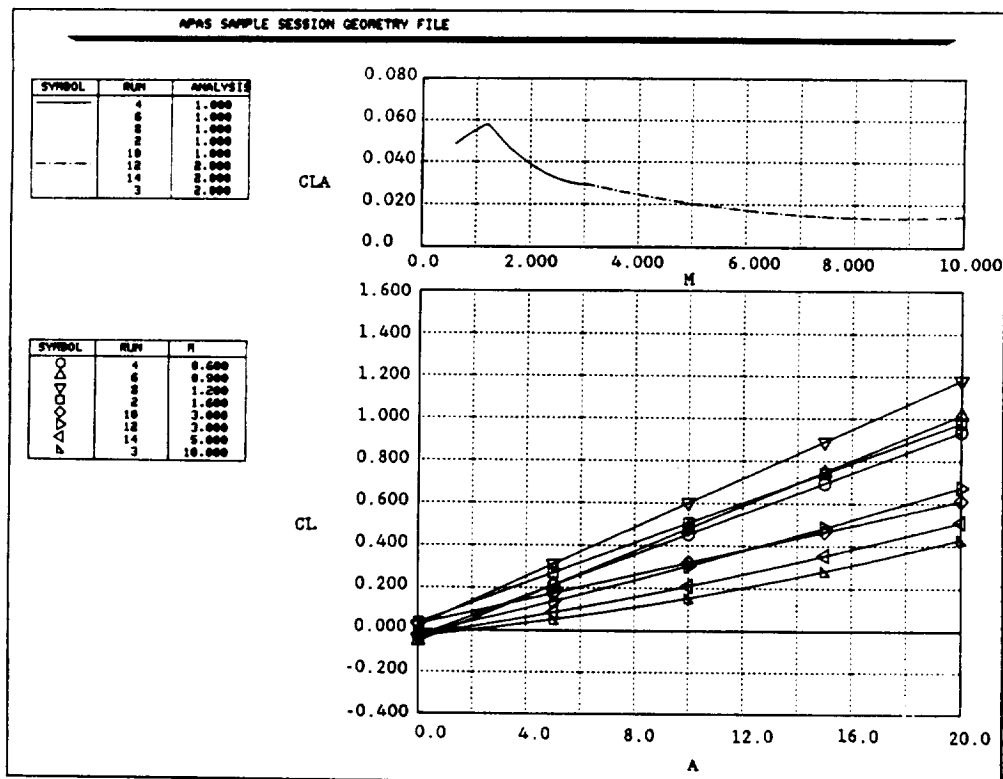


Figure 5-14. PLOT Form 2 Display.

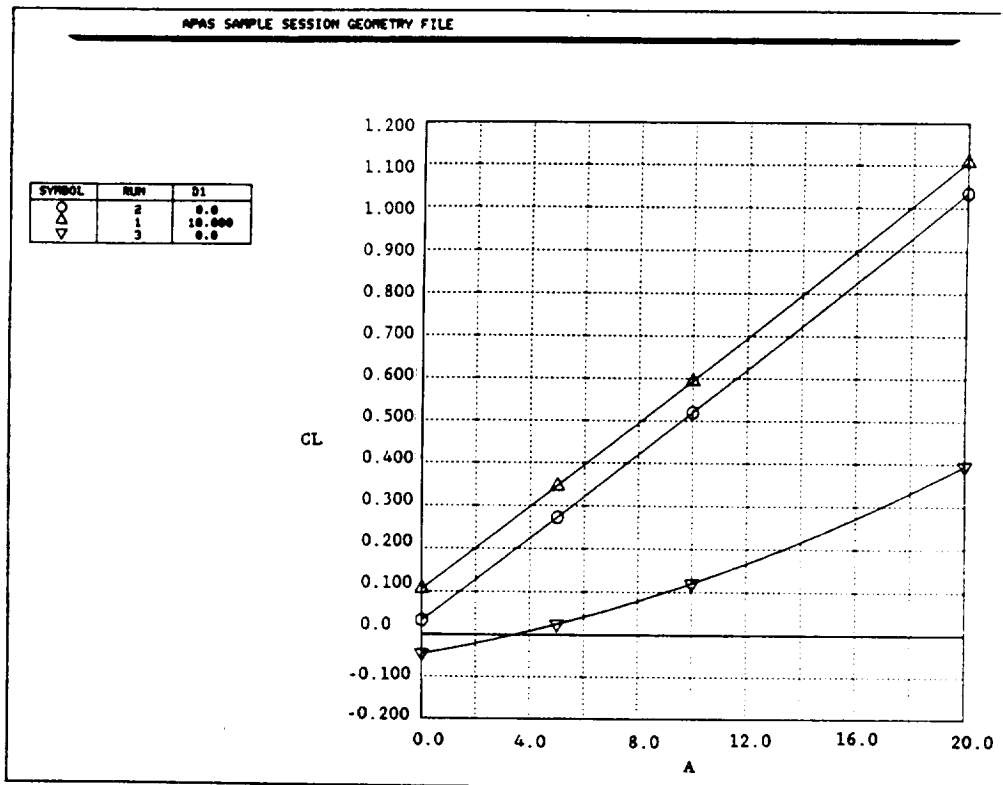


Figure 5-15. PLOT Form 3 Display.

SAMPLE SESSIONS

Review the PLOT command of section six prior to initiating this effort. Various subcommands will be demonstrated to familiarize the analyst with the system interactive display activity.

Constant Mach Number (Session 5-1)

Some of the aerodynamic results from the run list created in analysis session 4-2 will be displayed. In figure 5-16, the user enters the PLOT command and lists the runs available in the current output file on figure 5-17.

A plot of C_L versus angle of attack for runs 1, 2 and 3 is requested. The system searches the output file, selects the required data, and displays plotting information on figure 5-18. This screen will eventually clear and the requested plot will be displayed. Unresolved data will result in an error message, and the pre-plot page will remain. The PAGE operand of the PLOT subcommand can be used to set the screen to hold or copy mode instead of the automatic clear mode. The resulting display is shown on figure 5-19.

```

**OK**
--> plot
***PLOT***
--> 1

```

Figure 5-16. PLOT Command Entry and Listing of Runs Currently Available in the Output File.

```

RUN SUMMARY

RUN      M      A      B      P      Q      R      D1      D2      D3      D4      D5      D6 RUN STATUS
1      1.600  0.0  0.0  0.0  0.0  0.0  10.000  0.0  0.0  0.0  0.0  0.0  0.0 ANALYZED
2      1.600  0.0  0.0  0.0  0.0  0.0   0.0   0.0  0.0  0.0  0.0  0.0  0.0 ANALYZED
3     10.000  0.0  0.0  0.0  0.0  0.0   0.0   0.0  0.0  0.0  0.0  0.0  0.0 ANALYZED
***PLOT***
--> plot c1/a run(2,1,3)

```

Figure 5-17. Listing of Runs in Current Output File and Entering Subcommand to Display C_L Versus α .

```

FORM: 3

GRID: 1

PLOT DATA SUMMARY

CL      VS.      A

REFERENCE :      A      B      P      Q      R      D1      D2      D3      D4      D5      D6
DATA      :      0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

POINT  RUN  MACH  D1
1      2    1.600  0.0
2      1    1.600 10.000
3      3   10.000  0.0

ENTER "CARRIAGE RETURN" TO START PLOT, OR ENTER A NEW "PLOT" SUBCOMMAND:

NOTE: TO CONTROL PAGE STOP ON THIS PREPLOT PAGE USE "PAGE" OPERAND

--> <CR>

```

Figure 5-18. Pre-plot Page for Lift Display.

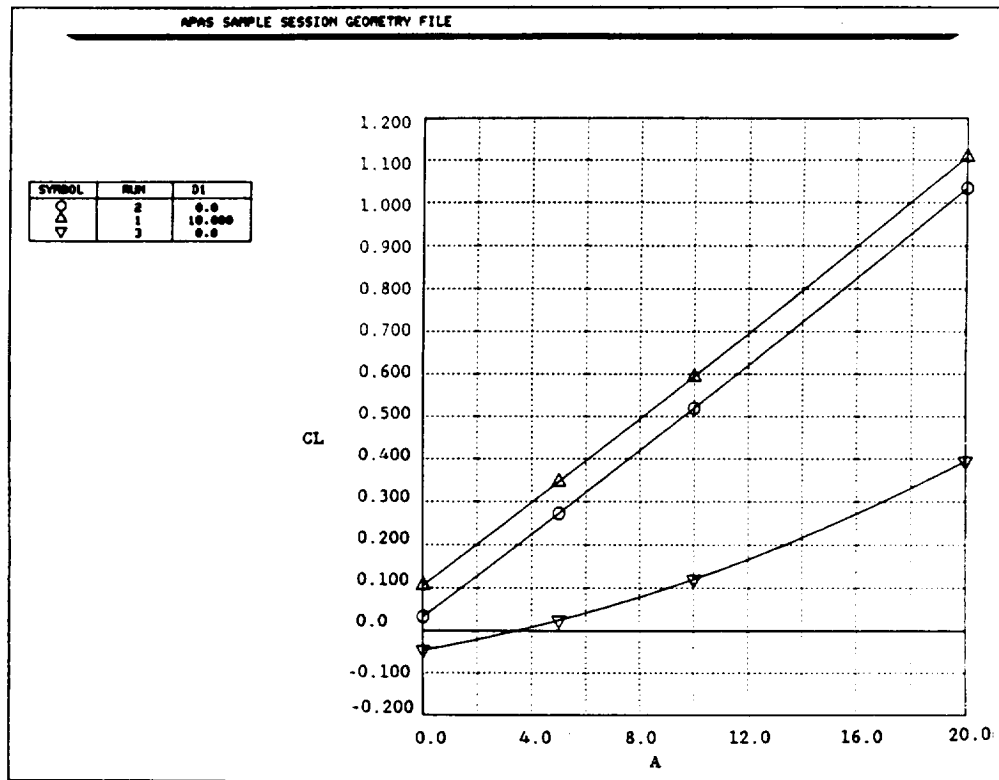


Figure 5-19. Display of C_L Versus α .

On figure 5-20, the new plot schedules are specified using the SET subcommand. After review a carriage return is keyed in to reactivate the ***PLOT*** mode. There are seven plot schedules which the user can display. To obtain a drag polar display plot schedule 3 is selected using plot3 entry. Note that it is not necessary to re-enter the run schedule keyed in on figure 5-17. The resulting pre-plot page and display are shown on figures 5-21 and 5-22.

```

***PLOT***
--> set1 cl/a
***PLOT SCHEDULE      1:
CL/A
***PLOT***
--> set2 cm/a
***PLOT SCHEDULE      2:
CM/A
***PLOT***
--> set3 cl/cd
***PLOT SCHEDULE      3:
CL/CD
***PLOT***
--> set4 f2 cla/m cl/a
***PLOT SCHEDULE      4:
F2 CLA/M CL/A
***PLOT***
--> set5 cla cra clo
***PLOT SCHEDULE      5:
CLA CMA CLO
***PLOT***
--> set6 cl/cm sa1=0.1
***PLOT SCHEDULE      6:
CL/CM SA1=0.1
***PLOT***
--> set7 cl/cd0 sa1=0.1 cl/cd100 sa2=0.1 cl/cd sa3=0.1
***PLOT SCHEDULE      7:
CL/CD0 SA1=0.1 CL/CD100 SA2=0.1 CL/CD SA3=0.1
--> <CR>
***PLOT***
--> plot3

```

Figure 5-20. Utilizing the SET Subcommand to Specify New Plotlists and Plotting the Current Runlist.

```

                                PLOT DATA SUMMARY
FORM:  3
GRID:  1
REFERENCE :    A    B    P    Q    CL    VS.    A
DATA      :    0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
          POINT  RUN    MACH    D1
            1    2    1.600    0.0
            2    1    1.600   10.000
            3    3   10.000    0.0

ENTER "CARRIAGE RETURN" TO START PLOT, OR ENTER A NEW "PLOT" SUBCOMMAND:
NOTE: TO CONTROL PAGE STOP ON THIS PREPLOT PAGE USE "PAGE" OPERAND
--> <CR>

```

Figure 5-21. Preplot Page for Drag Polar Display.

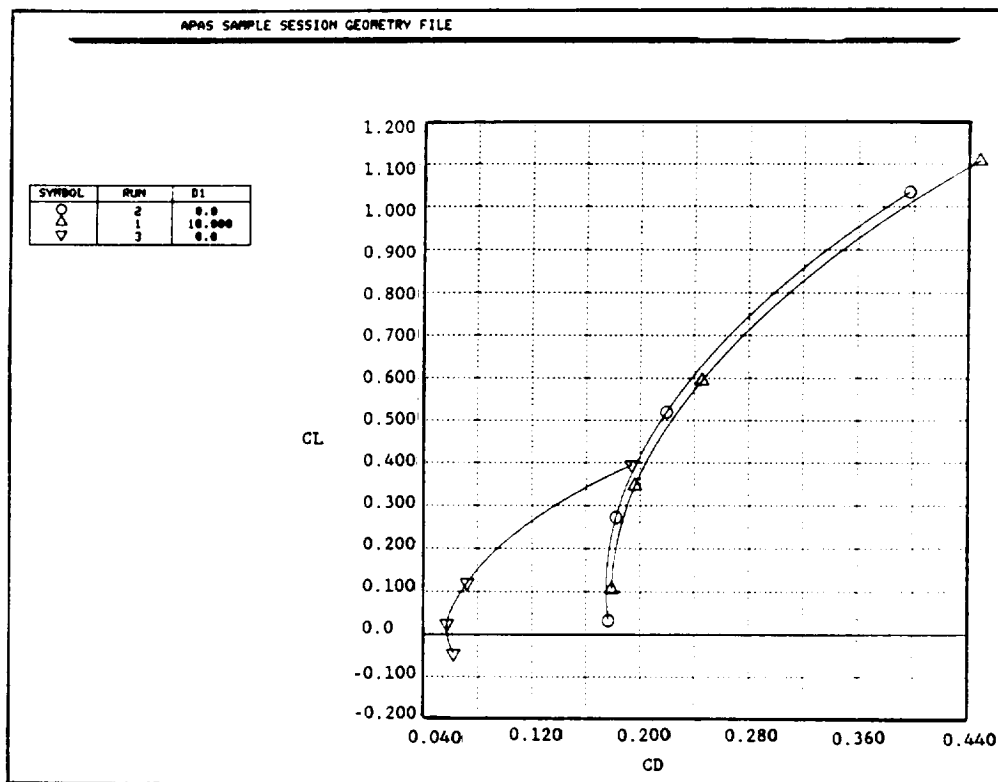


Figure 5-22. Display of Lift Versus Drag.

On figure 5-23, the runs available have been relisted for review, and a display of C_L has been selected with an abscissa scale (SA1) of 0.1. The resulting display is shown on figure 5-24.

RUN SUMMARY													
RUN	M	A	B	P	Q	R	D1	D2	D3	D4	D5	D6	RUN STATUS
1	1.600	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ANALYZED
2	1.600	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ANALYZED
2	1.600	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ANALYZED

PLOT

→→→ plot cl/cm sal=0.1

Figure 5-23. C_L Versus C_M Display Request.

SYMBOL	RUN	DI
○	2	0.0
△	1	10.000
▽	3	0.0

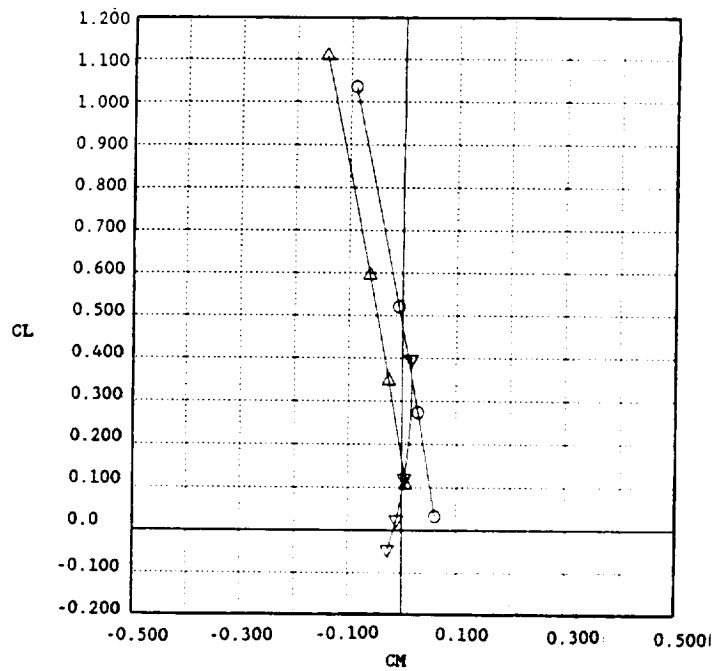


Figure 5-24. C_L Versus C_M Display.

The final activity of this session, requests the pitching moment plot for run 3 (figure 5-25), and is displayed on figure 5-26.

```
***PLOT***
--> plot cl/cm run(3) sal=0.1
```

Figure 5-25. Run 3 C_L Versus C_M Display Request.

SYMBOL	RUN	R
○	3	10.000

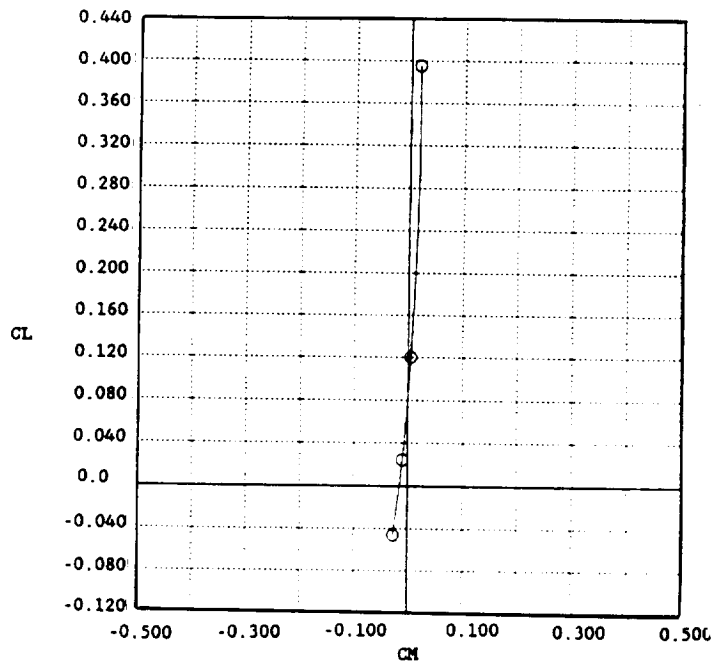


Figure 5-26. Run 3 C_L Versus C_M Display.

Variable Mach Number (Session 5-2)

A new set of analysis runs was processed and added to the output file for a total of 22. Runs 1 through 14 are pitch analysis with the trailing edge flap undeflected and deflected ten degrees. Runs 15 through 22 are side slip analysis at zero angle of attack. The new runs cover the subsonic, supersonic and hypersonic speed range of the study configuration. Runs 10 and 11 are linear supersonic analysis and runs 12 and 13 hypersonic evaluation for the same Mach numbers. As a result of the increased analysis coverage, a series of aerodynamic displays can be set up to summarize overall vehicle characteristics.

The SET subcommand of PLOT is used to request the longitudinal slope ($dC_L/d\alpha$, $dC_M/d\alpha$, dC_M/dC_L) preset plot list. The PLOT subcommand and RUN operand are then used to display the analysis results as a function of Mach number (figure 5-27). Runs 4, 6, 8, 2, and 10 are the subsonic-supersonic runs and are placed in ascending order. These are followed by the hypersonic runs 12, 14, and 3 also in ascending order. The RUNM operand partitions the list into 5 subsonic-supersonic cases and 3 hypersonic cases to identify the results by analysis method. The pre-plot page is shown on figure 5-28. The resulting display on figure 5-29.]

```
***PLOT***
--> set6

CURRENT PLOT SCHEDULE 6 IS:CLA/M(A=0) CMA/M(A=0) DCMDCL/M(A=0)
ENTER NEW PLOT SCHEDULE 6, OR "CARRIAGE RETURN" TO RETAIN AS IS
--> <CR>
***PLOT***
--> plot6 run(4 6 8 2 10 12 14 3 ) runm(5 3)
```

Figure 5-27. Input for Displaying Mach Number Variation of Longitudinal Aerodynamic Derivatives.

PLOT DATA SUMMARY

FORM: 3

GRID: 1

CLA VS. M

REFERENCE	:	A	B	P	Q	R	D1	D2	D3	D4	D5	D6
DATA	:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

POINT	RUN	MACH	ANALYSIS
1	4	0.600	1.000
2	6	0.900	1.000
3	8	1.200	1.000
4	2	1.600	1.000
5	10	3.000	1.000
6	12	3.000	2.000
7	14	5.000	2.000
8	3	10.000	2.000

GRID: 2

CMA VS. M

REFERENCE	:	A	B	P	Q	R	D1	D2	D3	D4	D5	D6
DATA	:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

POINT	RUN	MACH	ANALYSIS
1	4	0.600	1.000
2	6	0.900	1.000
3	8	1.200	1.000
4	2	1.600	1.000
5	10	3.000	1.000
6	12	3.000	2.000
7	14	5.000	2.000
8	3	10.000	2.000

GRID: 3

DCMDCL VS. M

REFERENCE	:	A	B	P	Q	R	D1	D2	D3	D4	D5	D6
DATA	:	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

POINT	RUN	MACH	ANALYSIS
1	4	0.600	1.000
2	6	0.900	1.000
3	8	1.200	1.000
4	2	1.600	1.000
5	10	3.000	1.000
6	12	3.000	2.000
7	14	5.000	2.000
8	3	10.000	2.000

ENTER "CARRIAGE RETURN" TO START PLOT, OR ENTER A NEW "PLOT" SUBCOMMAND:

NOTE: TO CONTROL PAGE STOP ON THIS PREPLOT PAGE USE "PAGE" OPERAND

Figure 5-28. Longitudinal Display Pre-plot Page.

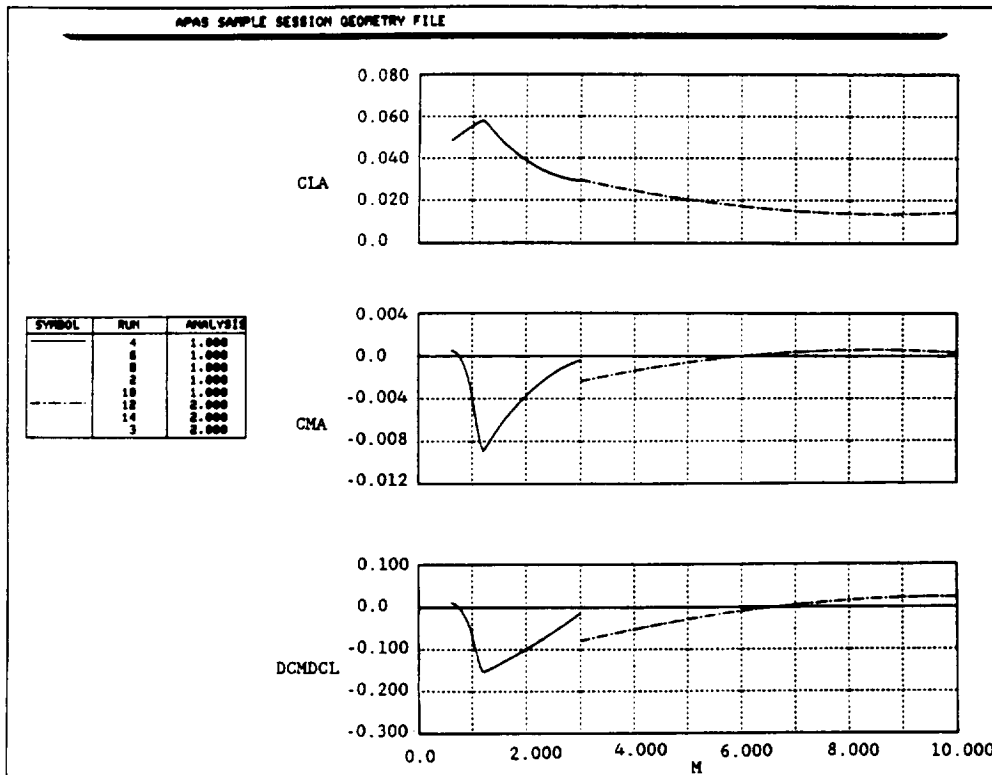


Figure 5-29. Mach Number Display of Longitudinal Characteristics.

Using form 2, a more detailed display can be made of individual characteristics. Figure 5-30 shows the input for displaying lift curve slope as a function of Mach number and lift versus angle of attack, and the resultant plot is shown on figure 5-31. The run list is the same as the previous plot. Similar inputs and displays are shown for longitudinal stability in screens 5-32 and 5-33, and drag in screens 5-34 and 5-35.

```

***PLOT***
--> plot cla(a=0) cl/a run(4 6 8 2 10 12 14 3) runm(5 3)

```

Figure 5-30. Input for Displaying Lift and Lift Curve Slope.

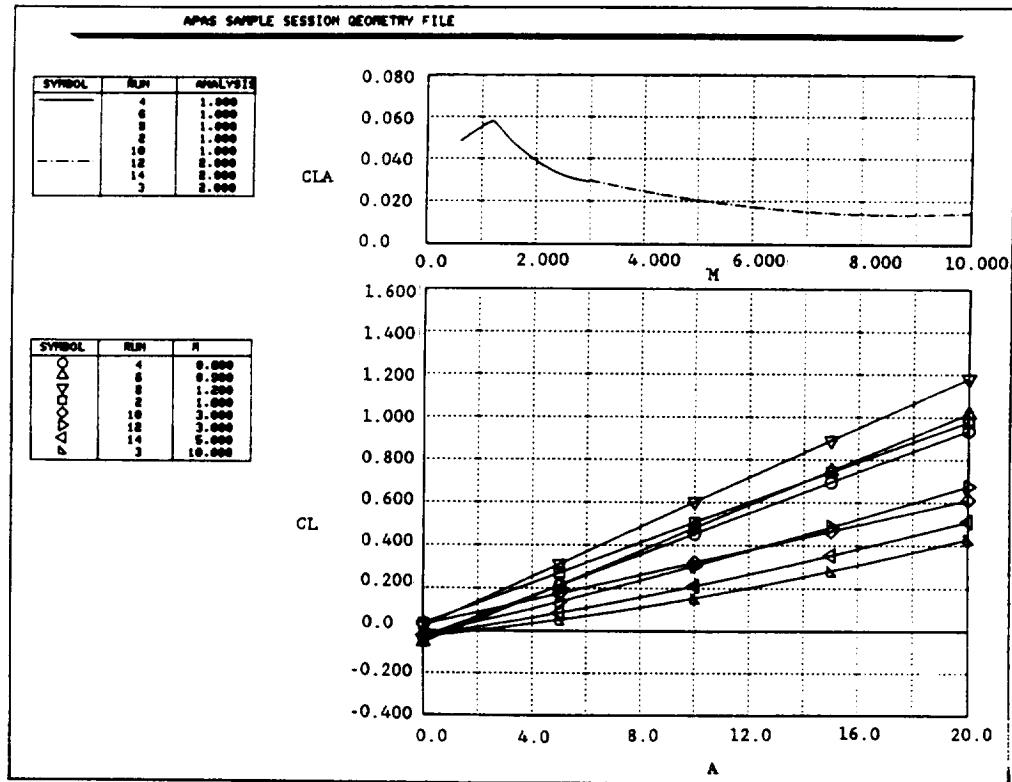


Figure 5-31. Lift Characteristics Displayed as a Function of Mach Number and Angle of Attack.

PLOT
 +-- plot dcmdcl(a=0) cl/cm runm(5 3)

Figure 5-32. Longitudinal Stability and Lift Versus Pitching Moment Display.

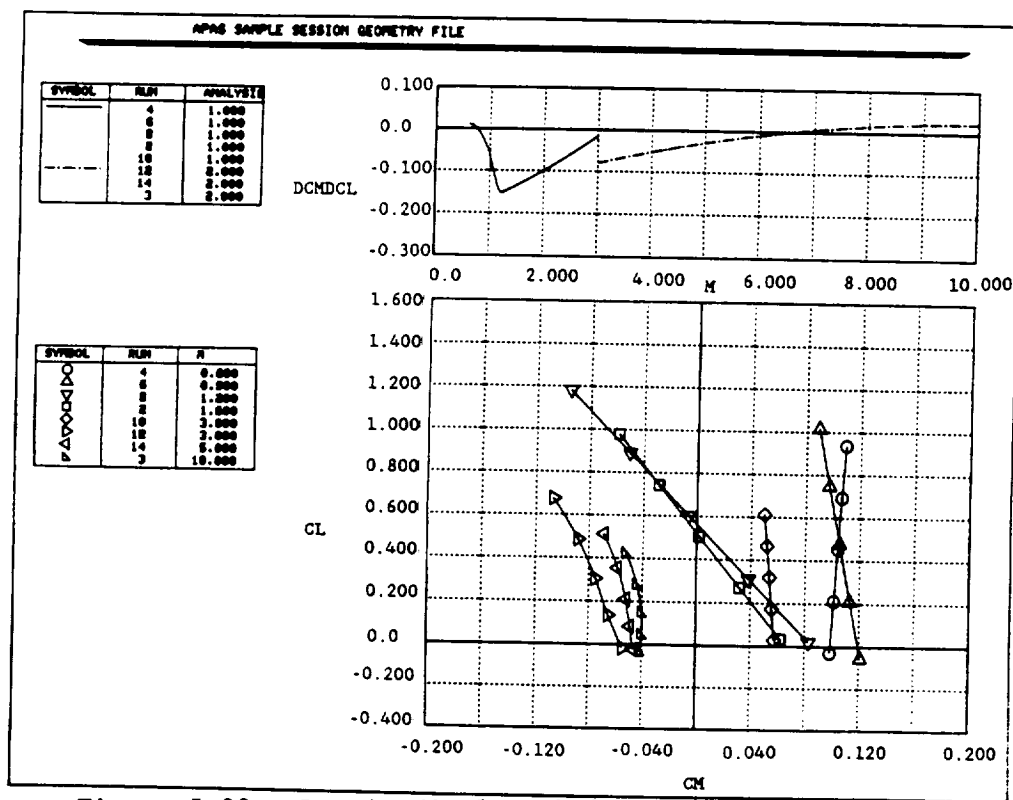


Figure 5-33. Longitudinal Stability as a Function of Mach Number and Lift Versus Pitching Moment.

```

***PLOT***
--> set

CURRENT PLOT SCHEDULES:
1. CL/A
2. CM/A
3. CL/CD
4. F2 CLA/M CL/A
5. CLA CMA CLO
6. CL/CM SA1=0.1
7. CL/CDO SA1=0.1 CL/CD100 SA2=0.1 CL/CD SA3=0.1
8. CDO/M(A=0.) CL/CD G1

CURRENT PLOT SCHEDULE 9 IS:
ENTER NEW PLOT SCHEDULE 9, OR "CARRIAGE RETURN" TO RETAIN AS IS
--> <CR>
***PLOT***
--> plot8 runm(5 3)

```

Figure 5-34. Drag at $\alpha=0$ and C_L Versus C_D Display Request.

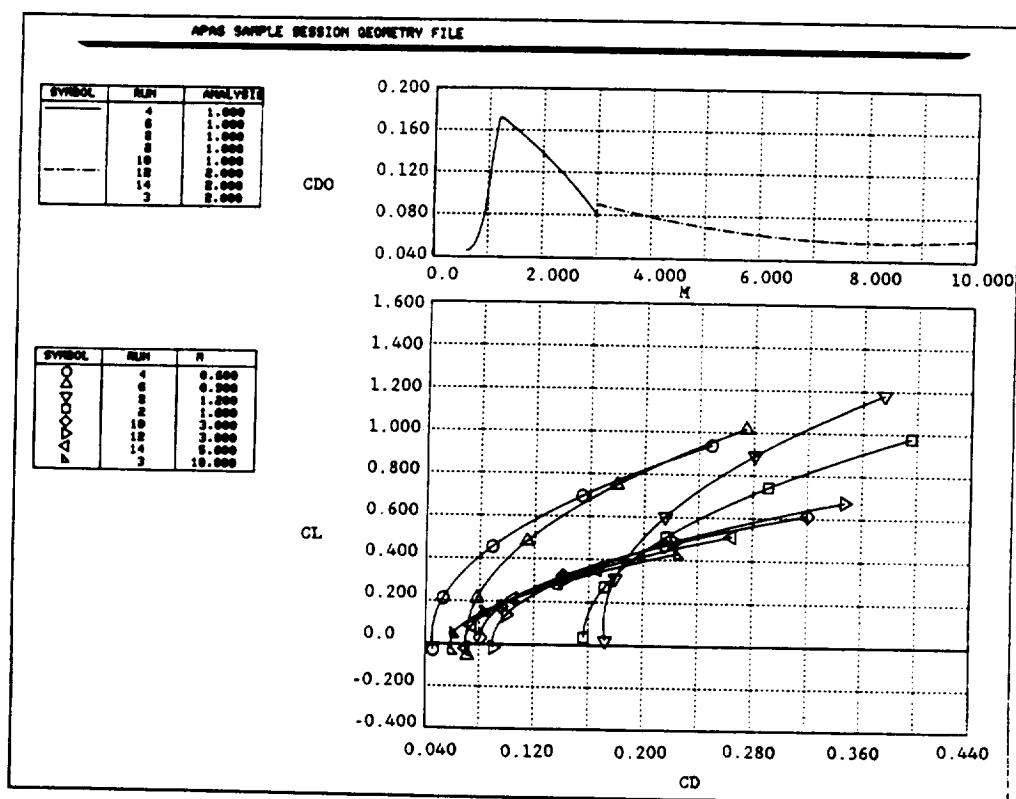


Figure 5-35. Drag Characteristics as a Function of Mach Number and Lift.

Similarly, the input and display shown on figures 5-36 and 5-37 summarize the lateral-directional characteristics (C_{y_β} , C_{n_β} , and C_{l_β}) from runs 15 through 22.

```

****PLOT***
--> plot cyb(b=0) cnb(b=0) crb(b=0) run(15 16 17 18 19 20 21 22) runm(5 3)

```

Figure 5-36. Input for Displaying Lateral-directional Characteristics as a Function of Mach Number.

Section 6

COMMAND/SUBCOMMAND DICTIONARY

General grouping of commands by system activity is presented on figure 6-1. System activity and commands as used in previous sections, is presented on table 6. Table 7 provides a command index.

Each command/subcommand begins with a summary description including examples. Information then follows on its detailed use. This format allows progressively reduced reading load with increasing experience. Once familiarization with the command structure is gained, many of the activities only require cursory review to recall mechanics.

The command summary has been designed to give as much information as possible on one page. Its format is as follows:

1. Name
2. Type of entry
3. Input format (always contained in a box)
4. List of operands and their function
5. Command/subcommand abbreviation
6. Function
7. Examples

A command and its associated operands are keyed in on one line. A typical directive is

$$\text{DISPLAY}, \left\{ \text{COMP}(1) [, \text{COMP}(2), \dots \text{COMP}(N)] \right\} [, \text{FILE}] [, \text{VIEW}] [, \text{ANGLE}, -\beta, \alpha, \gamma] <\text{CR}> \\ [, \text{ALL}]$$

where DISPLAY identifies the command desired and the square brackets are used to indicate optional operands which may be entered in any order. Nested brackets are used to separate the operands into logical groups. Strings of periods indicate to continued as in one through seven. The comma before each operand is a delimiter. A blank preceding each operand is also adaptable but was not used in order to explicitly indicate this point. In general a single comma, a single comma with one or more preceding or anteceding blanks, or one or more blanks are legal delimiters. Do not enter the brackets, as they have been used to separate the operands into logical groups and serve only this function.

The remainder of this section alphabetically defines system commands and subcommands. Their use is best learned by reviewing the cited examples and practicing the various operations. The default status for the file operand is taken to be PERMANENT to agree with the ATTRIBUTE declaration used throughout this document.

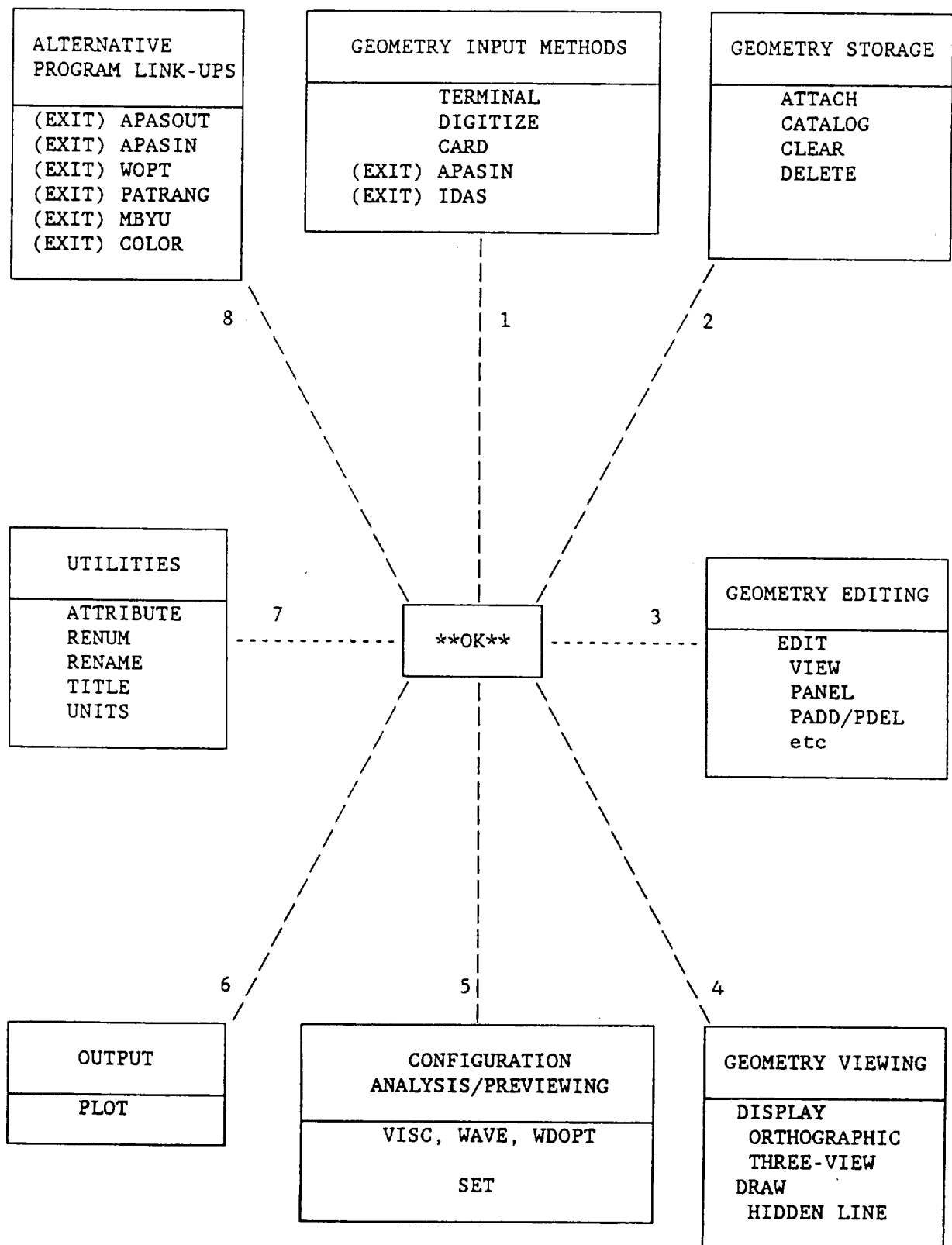


Figure 6-1. Command/Subcommand Summary by System Activity.

Table 6. System Activity and Commands Versus Section.

<u>SYSTEM ACTIVITY</u>	<u>SECTION</u>	<u>COMMAND</u>
Set Defaults (optional)	3	ATTRIBUTE
File Labeling	3	TITLE
Units Declaration	3	ATTRIBUTE UNITS
Configuration Definition	3	CARD DIGITIZE INTERFERENCE SLENDER TERMINAL
Display	3	DISPLAY
Component Editing and Paneling	3	EDIT
Component Management	3	ATTACH CATALOG CLEAR COPP COPY DELETE FILES RENAME RENUMBER STATUS
Foreground Analysis	4	VISCOUS WAVEDRAG
Background Analysis	4	SET
Analysis Plotting	4	PLOT
Exit	4	EXIT

Table 7. Command Index.

<u>Command</u>	<u>Subcommand</u>	<u>Page</u>
[ATTA]CH		135
[ATTR]IBUTE.		136
CARD		137
[CATA]LOG		138
CLEAR		139
COPP		140
COPY		141
[DEL]ETE		142
[DIGI]TIZE		143
[DISP]LAY		153
DR		154
EDIT		157
	A, B	158
	[DEL]ETE	159
	[DU]PLICATE	160
	DX, DY, DZ	161
	[E]ND	162
	[IN]SERT	163
	[L]IST	164
	PADD, PDEL	165
	[PAN]EL	166
	[P]ARAMETER	172
	RESECT	174
	[S]AVE	175
	SC	176
	SEG	177
	SPON, SDON	180
	SX, SY, SZ, ST	181
	[T]/C	182
	[VI]EW	183
	VON, VOFF	185
	X, Y, Z	186
	XH	187
EXIT		188
[FILE]S		189
FLAT		190
[INTE]REFERENCE		193
JETF		194
PANBDY		198
PLOT		199
	[E]ND	202
	LIST.	203
	PLOT.	204
	SET	207
[RENA]ME		208
[RENU]MBER		209

Table 7. Command Index (concluded)

SET	210
ADD	231
[DEL]ETE.	234
[E]ND	235
[L]IST.	236
PL	237
PR	239
[REF]ERENCE	243
RESET	244
[S]ET	246
[SLEN]DER	248
[STAT]US	250
[TERM]INAL	251
[TITL]E	256
[UNIT]S	257
[VISC]OUS	259
[WAVE]DRAG	263
WDOPT	265

-ATTACH-

COMMAND: ATTACH

$$\text{ATTACH, } \left\{ \begin{array}{l} \text{COMP(1) [,COMP(2),....COMP(15)]} \\ \text{[ALL]} \end{array} \right\} \text{[,FILE]}$$

OPERANDS: COMP(N) - Component number(s).

ALL - Attach all components from [,FILE].

FILE - [P]ERMANENT; Default.
[C]OMPONENT

ABBREVIATION: ATTA

FUNCTION: Copies non-redundant components from [FILE] into local file.

LIMITS: Fifteen (15) components per configuration. All components must have same units.

EXAMPLE: Figures 4-1, 4-11.

-ATTRIBUTE-

COMMAND: ATTRIBUTE

ATTRIBUTE

OPERANDS: None.

ABBREVIATION: ATTR

FUNCTION: Modification of system defaults.

PROMPTS:

PRESENT USER DEFAULTS:

FILE OPERAND FOR COMMANDS -----: PERMANENT
ANGLE OPERAND FOR DISPLAY COMMAND----: YAW=90.00 PITCH=0.0 ROLL=90.00
UNIT OPTION FOR UNITS COMMAND -----: METERS
LINE-TYPE OPTION FOR DISPLAY COMMAND : STICK
VIEW OPERAND FOR EDIT/LIST SUBCOMMAND: FULL DISPLAY

ENTER: "CR" - NO CHANGE

- 1 - FILE OPERAND
- 2 - ANGLE OPERAND FOR DISPLAY COMMAND
- 3 - UNIT OPTION FOR UNITS COMMAND
- 4 - VIEW OPERAND FOR DISPLAY COMMAND
- 5 - LINE TYPE OPTION FOR DISPLAY COMMAND
- 6 - VIEW OPERAND FOR EDIT/LIST SUBCOMMAND

Details associated with each option will be displayed upon interrogation.

- CARD -

COMMAND: CARD

CARD,COMP(1)[,COMP(2),....COMP(N)][,FILE]

OPERANDS: COMP(N) - Component number(s) in card file.

FILE - [P]ERMANENT; Default.
[L]OCAL

ABBREVIATION: None

FUNCTION: Copies component(s) from the card image format file into
[FILE].
Refer to Appendix A for input format.

LIMITS: Maximum 40 points per cross-section.
Maximum 10 segments per cross-section.
Maximum 17 cross-sections per component of the surface type.
Maximum 18 cross-sections per component of the body type.

EXAMPLE: CARD,101,L

-CATALOG-

COMMAND: CATALOG

CATALOG[,FILE]

OPERANDS: FILE - [P]ERMANENT; Default.
[B]OTH

ABBREVIATION: CATA

FUNCTION: Catalog component undergoing input into requested file. Protects old components with same number.

This command must be executed immediately after a component has been created using the CARD, DIGITIZE, FLAT, INTERFERENCE, JETF, SLENDER, or TERMINAL commands.

EXAMPLE: Figures 3-16, 3-21, 3-72.

- CLEAR -

COMMAND: CLEAR



CLEAR

OPERANDS: None.

ABBREVIATION: CL

FUNCTION: Purges all components in the local file.

-COPP-

COMMAND: COPP

$\text{COPP}, \left\{ \begin{array}{l} \text{COMP}(1) [, \text{COMP}(2), \dots \text{COMP}(N)] \\ [\text{ALL}] \end{array} \right\} [, \text{FILE}]$

OPERANDS: COMP(N) - Component number(s). [N≤50].

ALL - Attach all components from [,FILE].

FILE - [C]OMPONENT; Default.
 [L]OCAL

ABBREVIATION: None.

FUNCTION: Copy a component from [,FILE] into permanent file.
Protects existing components with same number.

EXAMPLE: COPP,ALL,C

-COPY-

COMMAND: COPY

COPY,COMP,COMPN[,FILE]

OPERANDS: COMP - Component number of the original component.
COMPN - Component number of the new duplicate component.
FILE - [P]ERMANENT; Default.
[L]OCAL

ABBREVIATION: None.

FUNCTION: Copy a component to a new record in the same file.

EXAMPLE: COPY,101,102,L

-DELETE-

COMMAND: DELETE

$$\text{DELETE, FILE, } \left\{ \begin{array}{l} \text{COMP(1) [, COMP(2) \dots , COMP(N)]} \\ \text{[ALL]} \end{array} \right\}$$

OPERANDS: FILE - [P]ERMANENT
 [L]OCAL

COMP - Component number.

ALL - Delete all components from specified file.

ABBREVIATION: DEL

FUNCTION: Eliminate components from specified file.

EXAMPLE: DEL,L,121,211

-DIGITIZE-

COMMAND: DIGITIZE

DIGITIZE[,COMPN][,AXIS][,FILE]

OPERANDS:


- COMPN - Add sections to component numbered COMPN.
- AXIS - New axis system requested.
Default: Axis defined on first call to digitize,
or previous axis on subsequent re-entries for
same COMPN.
- FILE - [P]ERMANENT; Default.
[L]OCAL

ABBREVIATION: DIGI

FUNCTION: Digitize component cross-sections from drawing using graphics tablet. A common set of units must be used.

EXAMPLE: Figures 3-48 through 3-55, 3-62 through 3-68.

-DIGITIZE- (continued)

<u>SYMBOL</u>	<u>DESCRIPTION</u>
[]	Information in bracket does not appear on screen. Information in bracket is point input from tablet.
	Indicated information is on graphics screen.
→→→	Tablet input using digitizing pen or puck.
<CR>	Carriage return.
•	Position of point to be input from tablet.
 <u>Variable</u>	
XO	Minimum x value from drawing.
XMAX	Maximum x value from drawing.
TYPE	1 - Non-planar centerline (eg. fuselage). 2 - Non-planar off-set (eg. engine pod). 3 - Half planar (eg. vertical tail). 4 - Full planar (eg. wing).
NSEG	Number of segments/section.
NWET(1)	Wetted-unwetted segment flag. Ten segments allowed per section. 1 - Wetted. -1 - Unwetted.
TOC	t/C max of airfoil. TOC < 0; Input airfoil section. TOC > 0; Last input airfoil section scaled to new chord and TOC.

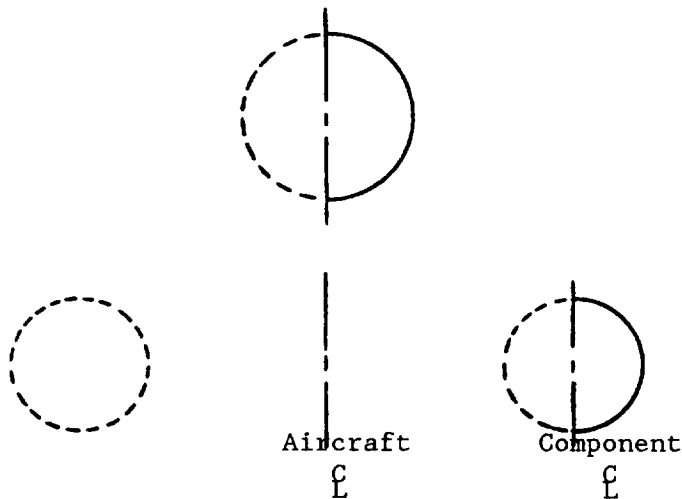
Component Symmetry Parameters

_____ Stored boundary

----- Generated by symmetry directive

Codes

{	1 Non-reflective	}	About aircraft centerline
	2 Reflective		
{	+ Asymmetric	}	About component centerline
	- Symmetric		



Reflective Asymmetric

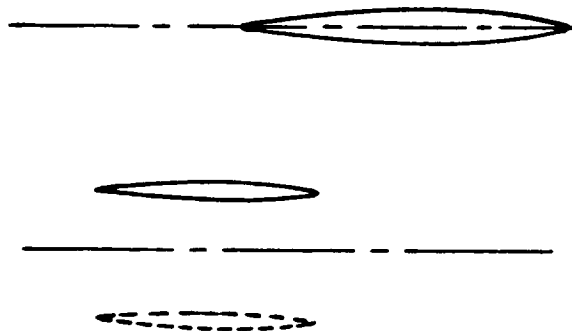
Code = 2

Example: Fuselage
Fuselage-Nacelles

Reflective Symmetric

Code = -2

Example: Missiles
Podded Nacelles



Non-reflective Asymmetric

Code = 1

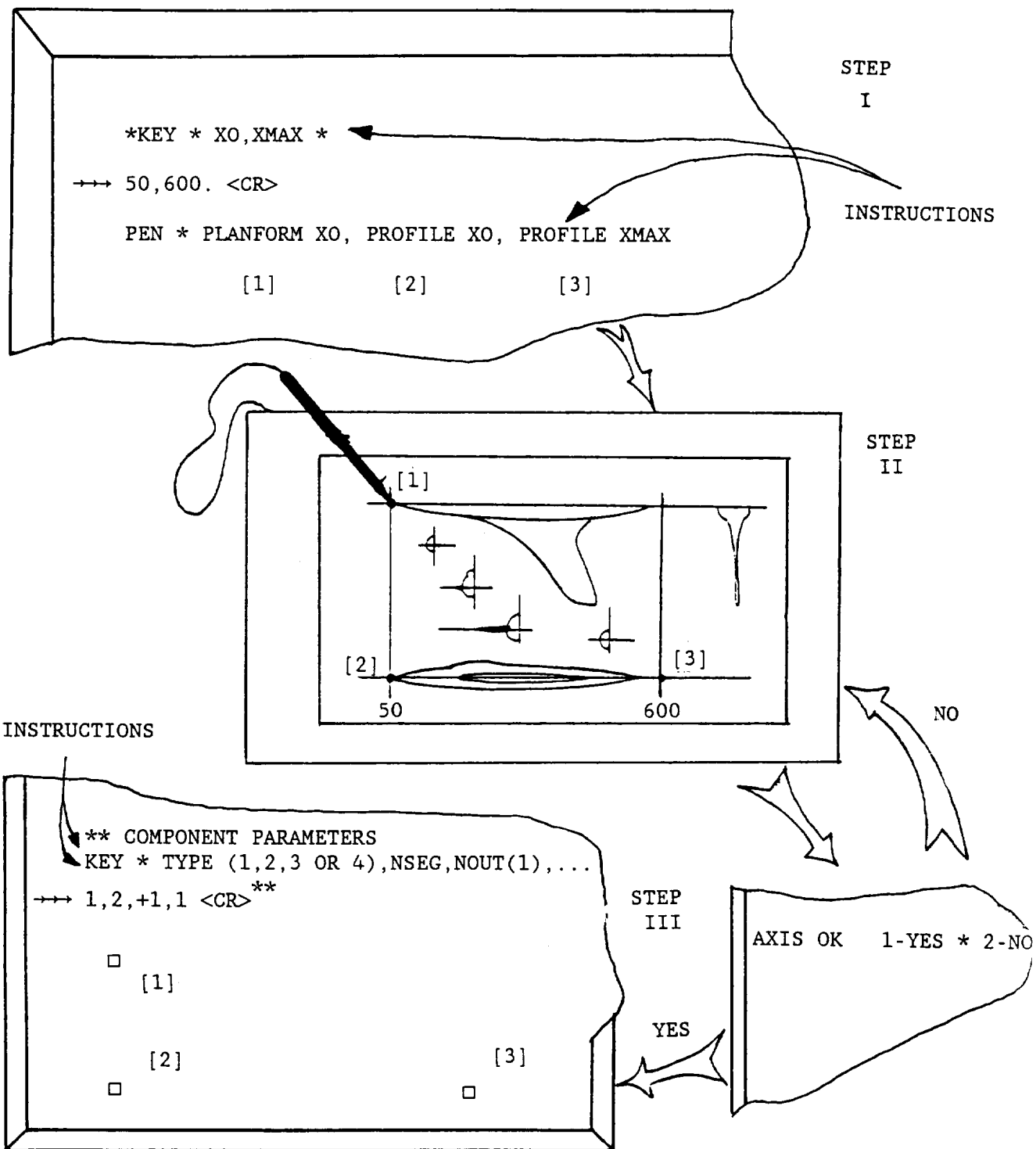
Example: Centerline Vertical

Reflective Asymmetric

Code = 2

Example: Winglets or
Twin verticals

SET UP AXIS SYSTEM



** IF POINTS [1] [2] [3] ARE INPUT INCORRECTLY ENTER 0,0,0 AND REPEAT II

INPUT COMPONENT NUMBER

→→→ number

INPUT COMPONENT NAME

→→→ name

ENTER SYMMETRY PARAMETER

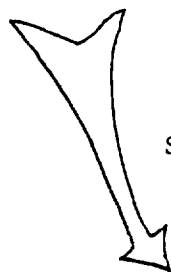
1 NON-REFLECTING

2 REFLECTING

+ ASYMMETRIC

- SYMMETRIC

→→→ symmetry parameter



SURFACE

GO TO STEP
IV-A



BODY

GO TO STEP
IV-B

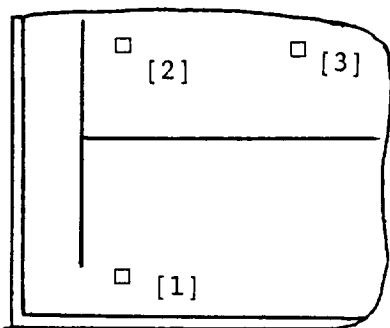
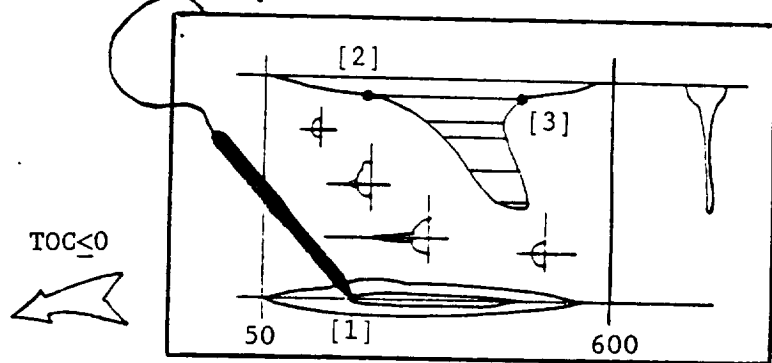
SURFACE INPUT

KEY * TOC: SET NEGATIVE TO INPUT AIRFOIL.
SET POSITIVE TO SCALE LAST INPUT AIRFOIL.
DEFAULT IS REFERENCE AIRFOIL T/C.

STEP
IV-A

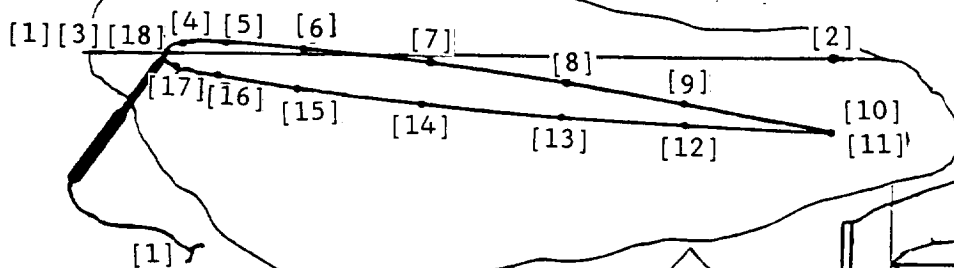
PEN * LE(PROFILE), LE AND TE (PLANFORM CHORD LENGTH)
IF TOC < 0, SECTION LE AND TE REFERENCE (IF DIFFERENT)
AIRFOIL SECTION FROM TOP L.E.

STEP
V-A



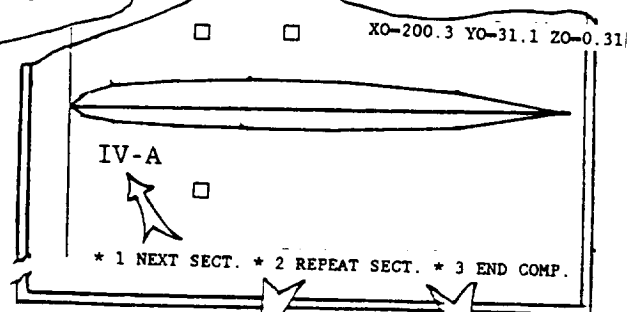
TOC ≤ 0

POINTS [3]-[10] SEGMENT 1
POINTS [11]-[18] SEGMENT 2

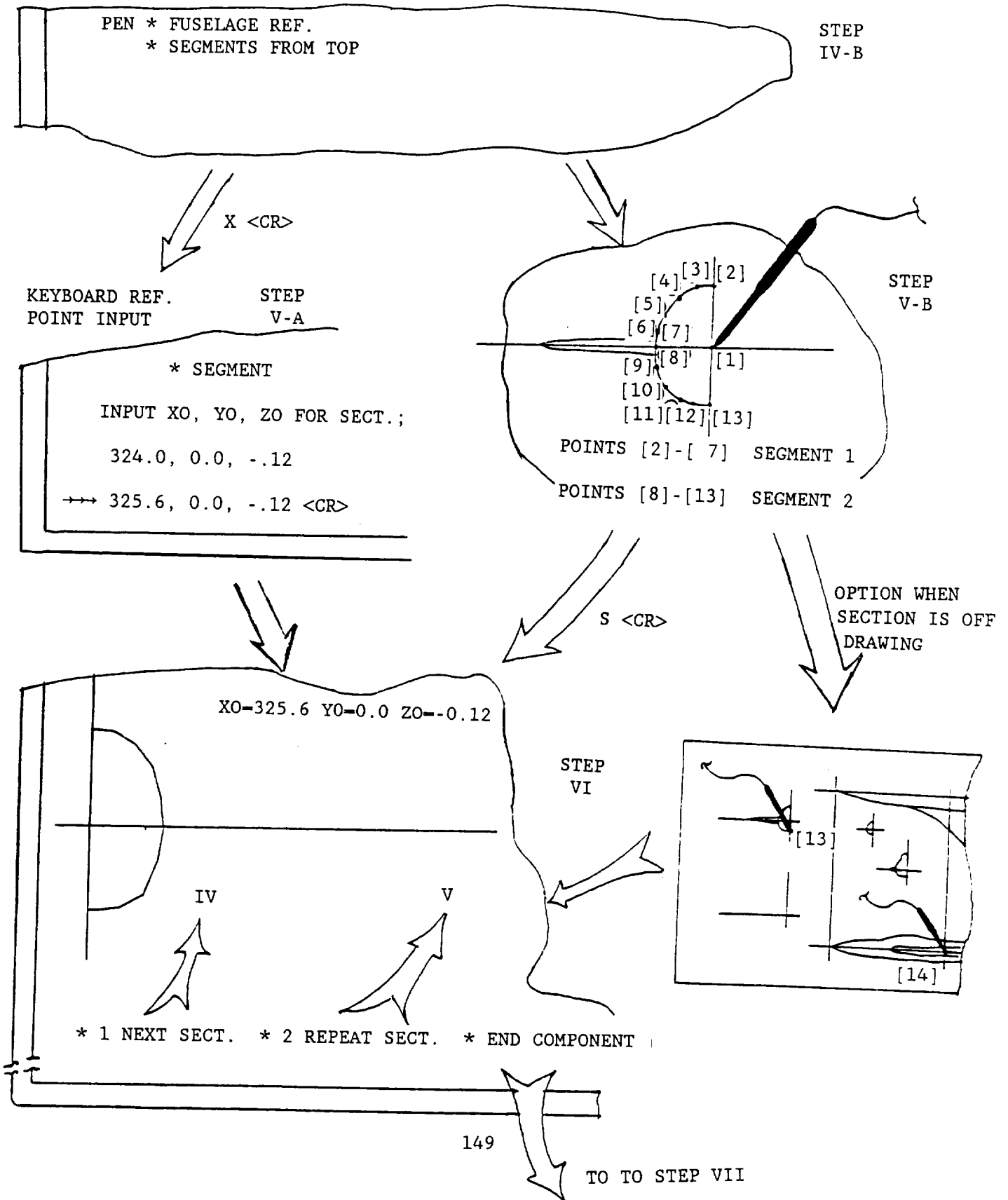


TOC > 0

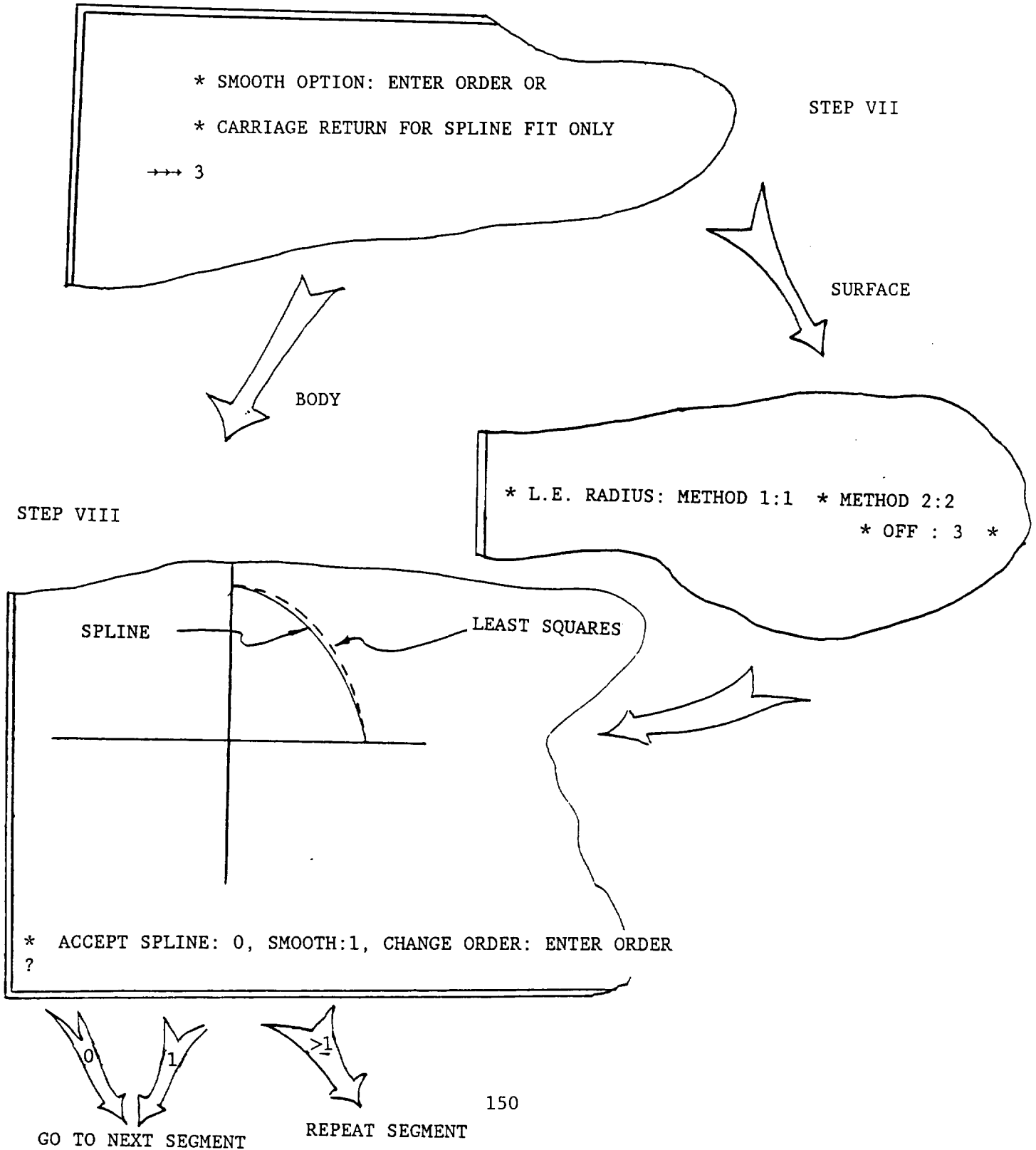
STEP
VI-A



BODY INPUT

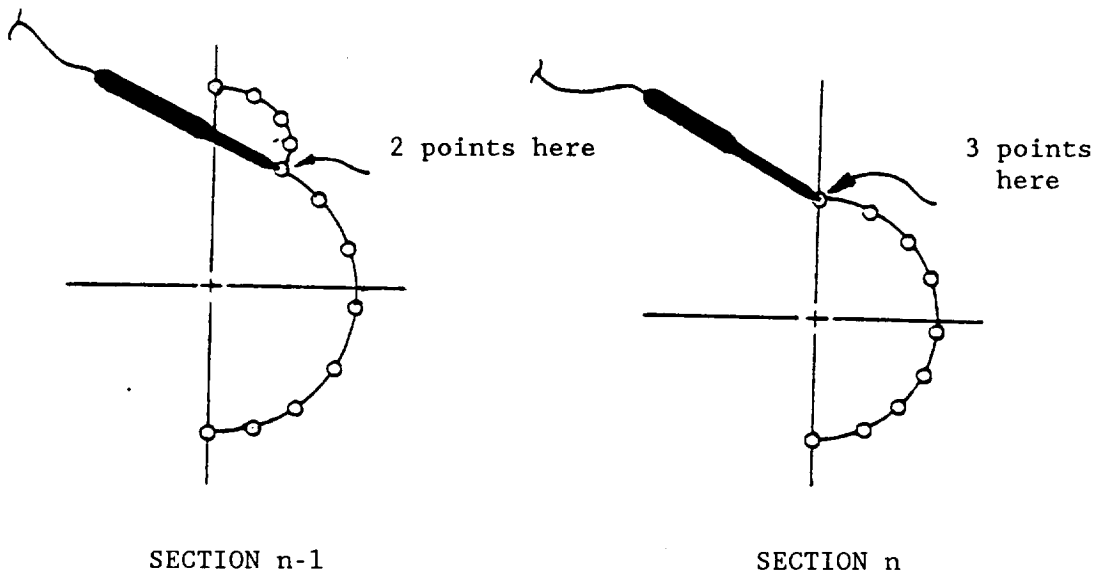


SEGMENT INTERPOLATION/SMOOTHING



NOTES

- 1) X0 and XMAX do not have to extend the length of the tablet or encompass the entire configuration. They are simply two convenient points on the drawing.
- 2) The X0 in the plan view and profile view must be the same X-station.
- 3) When a change in segments occurs, the user inputs two points at the same location. If two or more segments occur at the same point (i.e. segments of zero length such as would occur on the cross-section at the end of a canopy. See below), the user should input a number of identical points equal to the number of segments, i.e. if three segments meet at the same point three points are input.



The first and last points on a section do not require multiple points unless segments converge or originate there.

-DIGITIZE- (concluded)

- 4) The latest airfoil is always the reference section. A default section can only be used if the planar component has two segments.
- 5) Three airfoil nose options are available: a default sharp edge, a radius based on the input points ahead of the maximum thickness, or NACA four and five digit airfoil values given by

$$R_{LE}/c = 0.685 (t/c)^2 \quad [\text{NACA 64 A}]$$

$$R_{LE}/c = 0.639 (t/c)^2 \quad [\text{NACA 65 A}]$$

- 6) The multipoint routine used for graphics tablet digitizing has three termination options.
 - S <CR> indicates the cross-section is completed.
 - R <CR> indicates an error has occurred and input is being reinitiated.
 - X <CR> allows keyboard correction of the sections x-location.
- 7) The maximum number of input points per cross-section is forty including reference points such as the center line for a body section or chord markers for an airfoil.
- 8) Restoring the Tablet Bias

About once a week the tablet's magnetic bias should be restored. The following procedure can be used more often if the tablet begins to relay incorrect data or if the graphics cursor moves erratically.

- a. Turn the terminal off and unplug it.
- b. Disconnect the tablet from the interface.
- c. Pull the bar magnet across the tablet from the upper left corner towards the lower right corner in a single, smooth motion. Wipe the entire surface in about two or three seconds.
- d. Connect the tablet again, plug the terminal back in, and turn the terminal back on.

The magnet should be stored away from the tablet and other magnetically sensitive items (such as flexible disks and magnetic tapes).

-DISPLAY-

COMMAND: DISPLAY

$$\text{DISP}, \left\{ \text{COMP}(1) [\text{COMP}(2), \dots \text{COMP}(N)] \right\} [, \text{FILE}] [, \text{VIEW}] [, \text{ANGLE}, \text{yaw}, \text{pitch}, \text{roll}],$$

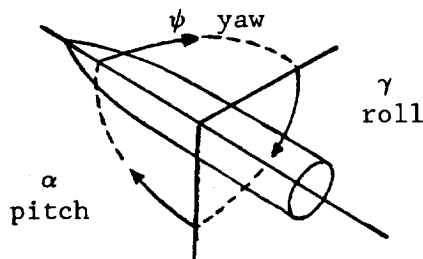
$$[\text{ALL}] [\text{HIDD}]$$

OPERANDS: COMP(N) - Component number(s); default is [ALL].

FILE - [P]ERMANENT; Default.
[L]OCAL

```
VIEW      - [T]HREE View STICK; Default*.
           Use L-,R-keys at cross hairs location to obtain view
           of a cross-section to left or right. E-key to end
           section loop request, followed by E-key to end EDIT.
           [O]RTHOGRAPHIC View STICK
```

```
[A]NGLE - Yaw,pitch,roll viewing angles (Orthographic only)
          YAW= 90.0, PITCH= 0.0, ROLL= 90.0 are defaults*.
          0,0,0 provides a head on view (nose to tail).
          135.0,-20 provides a nice view from left, rear.
```



HIDD - Poor man's hidden view (only forward facing panels displayed).
This is available only with Orthographic view.

ABBREVIATION: DISP

FUNCTION: Display component(s) in orthographic projection or three-view.
 Stick or hidden panel* line type is available.
 Orthographic has the following option menu.

```
* 1 VIEW      *
* 2 WINDOW    *
* 3 ZOOM OUT  *
* 4 PERS ON   *
* 5 PERS OFF  *
* E END       * [returns user to **OK** mode]
* ENTER COMMAND:
```

EXAMPLE: Figures 3-11 to 3-15, 3-33, 3-40, 3-55, 3-73.

*Set with ATTRIBUTE command.

-DR-

COMMAND: DR

DR

OPERANDS: None.

ABBREVIATION: None.

FUNCTION: Draws 3-D views, with or without hidden lines, of paneled components. Slender bodies may also be displayed instead of interference shell. Useful for checking whether panel edges are connected, and that all downstream panel edges follow upstream ones.

EXAMPLE:

PROMPT/RESPONSE:

→→→ DR

PLOT SLENDER BODY PANELING? Y=1, N=2

→→→ 2

ENTER CONFIG NUM OR CARRIAGE RETURN TO USE LOCAL FILE

→→→ <CR>

LOCAL FILE CONTENTS - - WILL BE DISPLAYED

COMPONENT NO.	NAME	ITYPE	ISYM
11.00	FORWARD FUSELAGE	1	2
12.00	MID FUSELAGE	1	2
13.00	AFT FUSELAGE	1	2
14.00	POD	2	2
15.00	BODY FLAP	4	2
121.00	WING	4	2
211.00	VERTICAL	3	1
611.00	SLENDER BODY	7	2

ENTER 0 TO END

ENTER 1 TO DRAW ALL PANELS OF CONFIGURATION

1.0 RIGHT SIDE

1.1 LEFT SIDE

1.2 RIGHT AND LEFT SIDE

ENTER 2 TO DRAW A PARTIAL CONFIGURATION

2.0 RIGHT SIDE

2.1 LEFT SIDE

2.2 RIGHT AND LEFT SIDE

→→→ 1.2

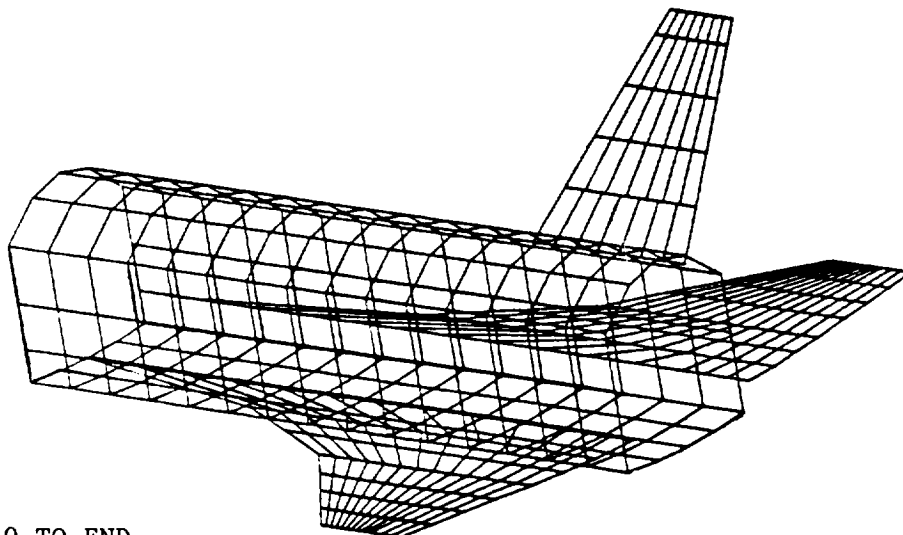
-DR- (continued)

INPUT DISPLAY ANGLES (YAW,PITCH,ROLL):

PANELS 1 THRU 234

?

45 5 20



ENTER 0 TO END

ENTER 1 TO DRAW ALL PANELS OF CONFIGURATION

1.0 RIGHT SIDE

1.1 LEFT SIDE

1.2 RIGHT AND LEFT SIDE

ENTER 2 TO DRAW A PARTIAL CONFIGURATION

2.0 RIGHT SIDE

2.1 LEFT SIDE

2.2 RIGHT AND LEFT SIDE

ENTER 3 TO DRAW WITH HIDDEN LINES REMOVED

→→→ 3

[IBM 3081 CPU TIME(SEC)]

SUBROUTINE TRIANG IS BEING CALLED TIME = 0.312

SUBROUTINE TRIANG IS COMPLETE DT = 0.007

SUBROUTINE OVRLAP IS BEING CALLED TIME = 0.334

TOTAL NUMBER OF POINTS IN OVERLAP TABLE: 11861

TOTAL POINTS ALLOWED: 70000

MAXIMUM OVERLAP FOR ANY TRIANGLE: 57

SUBROUTINE OVRLAP IS COMPLETE DT = 0.882

SUBROUTINE PRIOR IS BEING CALLED TIME = 1.216

SUBROUTINE PRIOR IS COMPLETE DT = 1.912

SUBROUTINE VISIBL IS BEING CALLED TIME = 3.128

SUBROUTINE VISIBL IS COMPLETE DT = 1.087

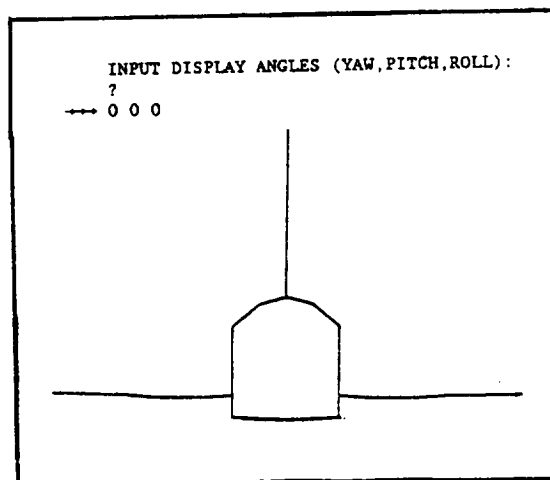
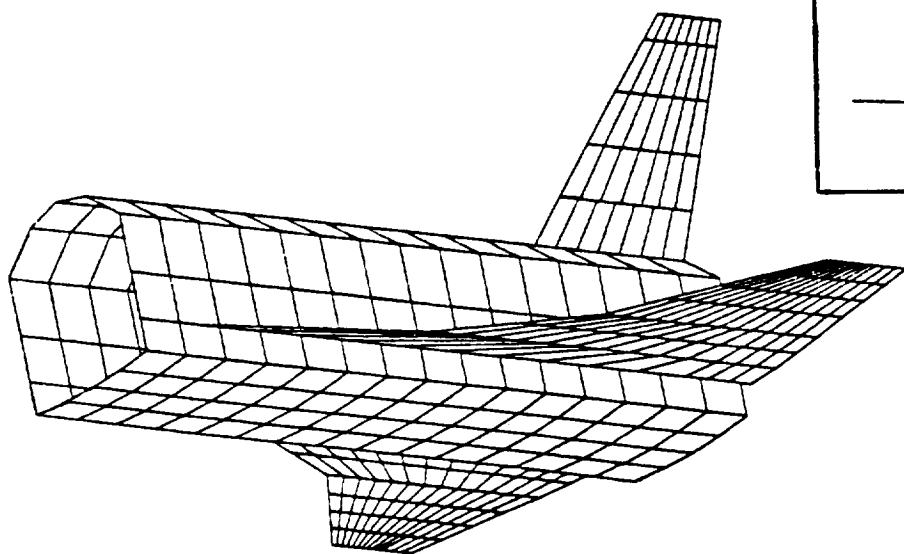
TOTAL TIME FOR HIDDEN LINE SOLUTION - 3.903

-DR- (concluded)

DISPLAY ANGLES

YAW,PITCH,ROLL

PANELS 1 THRU 234



The example shown here used the local file as its source of components. Another source of components that can be plotted are those associated with a particular configuration number as defined in the SET command. If components in a local file are used for the display, the DR command will actually use components in the permanent file that have the same component numbers.

LIMITS: A maximum of 500 panels can be displayed.

-EDIT-

COMMAND: EDIT

EDIT[,COMPN][,FILE][COMPREF₁....,COMPREF_n]

OPERANDS: COMPN - Component Number; Default is component in core.

 FILE - [P]ERMANENT; Default.
 [L]OCAL
 [C]OMPONENT

 COMPREF_i - Reference component(s) used in VIEW subcommand.

ABBREVIATION: None.

FUNCTION: Section listing and editing. Sections can be displayed, inserted, modified, or deleted. Full component editing is performed in edit using the VIEW subcommand. Paneling surface components for the lifting surface analysis program (UDP) is performed using the PANEL subcommand.

LIMITS: 40 Points per cross-section [TYPES 1 through 4].
 10 Segments per cross-section.
 25 Cross-sections per component (Remember that wave drag analysis adds 2 sections to each TYPE 1 or 2 component).
 500 Points per component.

Each TYPE 1 or 2 cross-section must have a constant x-value

Each TYPE 3 or 4 cross-section must have points on upper lower surface in matching pairs, each pair having the same x-value. Initial incidence (specified with EDIT/PARAMETER subcommand) may be set to a nonzero value of ALP, but remember that the rotation is done about the Xo,Yo,Zo global coordinate.

EXAMPLE: Figures 3-16 through 3-40, 3-74 through 3-87.

-EDIT-/A,B

SUBCOMMAND: A,B

[SEC,]*=VAL[,N1,N2][,N3][,V]
*=A or B

OPERANDS:

SEC - Section number; Default is current section.

VAL - Value of angle for rotation (degrees).
- counter-clockwise
+ clockwise
(Must be preceded by an "=" sign)

N1,N2 - Start point and end point of points to be rotated.
If N1 is greater than N2, rotation takes place
on points not between N1 and N2.

N3 - Point to rotate about, default is N1.
If N3 specified N1, N2 must be entered.

Default: If N1, N2, N3 are omitted, all points in
section are rotated about point 1.

V - Verify input value.

ABBREVIATION: None.

FUNCTION: Rotate body or airfoil sections.

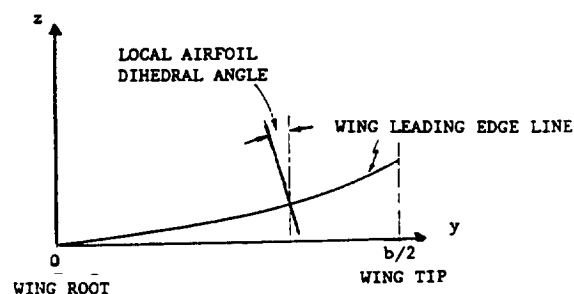
BODY (TYPE 1 and 2)

A - Rotate section about component y-axis.
B - Rotate section about component z-axis.

AIRFOIL (TYPE 3 and 4)

A - Incremental rotation angle $< \pm 90^{\circ}$
B - Absolute dihedral angle of airfoil.
Zero is parallel to aircraft xz-plane of
symmetry.

EXAMPLE: 1,A=6.0,V



-EDIT-/DELETE

SUBCOMMAND: DELETE

DELETE,N1[,N2][,V]

OPERANDS: N1 - Section to delete.
 N2 - Delete sections from N1 to N2.
 V - Verify input section.

ABBREVIATION: DEL

FUNCTION: Delete sections from component geometry.

EXAMPLE: DEL,2,3,V

-EDIT-/DUPLICATE

SUBCOMMAND: DUPLICATE

DUPLICATE=VAL,N1[,V]

OPERANDS: VAL - Interior location of new section.
 (Must be preceded by an "-" sign)

 for TYPE 1 and 2 body components
 x-location of new section

 for TYPE 3 and 4 wing components
 η -location of new section
 z/b for TYPE = 3 (Assuming 90 deg dihedral.)
 2y/b for TYPE = 4 (Assuming 0 deg dihedral.)

 N1 - Section to be duplicated.

 V - Verify new section.

ABBREVIATION: DU

FUNCTION: Duplicate section N1 at location VAL

EXAMPLE: DU=9.5,4,V; Assuming TYPE 1 or 2 body component.

-EDIT-/DX,DY,DZ

SUBCOMMAND: DX, DY, DZ

[SEC,]D*-VAL[,PNT1,PNT2][,V]
 *=X or Y or Z
or,
D*-VAL[,SEC1,SEC2][,ALL][,V]

OPERANDS: SEC - Section number; Default is current section.
VAL - Value to be added to *-points. (*=x or y or z)
(Must be preceded by an "=" sign)
PNT1,PNT2 - Add increment only to *-points from PNT1 to PNT2.
Default (no entry) increment all *-points in section.
V - Verify with printout of incremented *-points.
Default suppresses printout of incremented *-points.

In second form of command the following additional operands are used.

SEC1,SEC2 - Add increment only to *-points in SEC1 to SEC2.
ALL - Add increment to all *-points in each section.

ABBREVIATION: None.

FUNCTION: Add incremental value to x, y or z in a given section using subcommand DX, DY, or DZ, respectively.

EXAMPLES: Figures 3-23, 3-24.
1,DX=0.5 [Deltas X-points (all) in section 1 by 0.5]
3,DZ=0.5,1,11,V [Deltas Z-points from 1-11 in sect 3 by 0.5]
or,
DX=0.5,3,5,ALL [Deltas ALL X-points in sections 3-5 by 0.5]

-EDIT-/END

SUBCOMMAND: END



END

OPERANDS: None.

ABBREVIATION: E

FUNCTION: Ends editing activity of EDIT and returns the user to the
 OK mode.

EXAMPLE: Figure 3-20.

-EDIT-/INSERT

SUBCOMMAND: INSERT

INSERT=VAL[,V]

OPERANDS: VAL - Interior location of new section.
 (Must be preceded by an "=" sign)

 for TYPE 1 and 2 body components
 x-location of new section

 for TYPE 3 and 4 wing components
 η -location of new section
 z/b for TYPE = 3 (Assuming 90 deg dihedral)
 2y/b for TYPE = 4 (Assuming 0 deg dihedral)

 V - Verify new section.

ABBREVIATION: IN

FUNCTION: Spline interpolate a new section at location VAL on a
 segment by segment basis.

EXAMPLE: IN=9.503,V; Assuming TYPE 1 or 2 body component.

-EDIT-/LIST

SUBCOMMAND: LIST

[SEC,]LIST[,SP][,SD]

OPERANDS:

- SEC - Section number; omit for current section.
L for first section or L,L for last section.
- SP - Display section but suppress x,y,z values.
- SD - List x,y,z values but suppress display of section.

Defaults: List data and display section.
Change with ATTRIBUTE command.

ABBREVIATION: L

FUNCTION: Display section and list x, y, z coordinates. Multiple points correspond to beginning and end points of segments.

EXAMPLE: 2,L
Figures 3-22, 3-23, 3-28.

-EDIT-/PADD,PDEL

SUBCOMMAND: PADD, PDEL

PADD or PDEL

OPERANDS: None.

ABBREVIATION: None.

FUNCTION: Remove or add one or more points to each section of a body component (TYPE 1 and 2).
Remember that all sections in a component must have the same number of points.
Also, each segment in one section must have the same number of points in all other sections.

EXAMPLE: PADD

-EDIT-/PANEL

SUBCOMMAND: PANEL

PANEL[,NOSEC][,VERIFY]

OPERANDS: [N]OSEC - Only root and tip sections in component will be used to define region boundaries.
Default: All component sections are used to define region boundaries.

[V]ERIFY - Verify region, flap, and panel specifications.

ABBREVIATION: PAN

FUNCTION: Definition of subsonic-supersonic analysis regions, using flap boundaries and panel specification by region for surface components (TYPES 3 through 5).

OPERATION: A planer view of the surface component is displayed with a menu of key functions. Data is input by graphics cursor and keyboard.

LIMITS: 500 Total panels.
20 Panels chordwise.
50 Panels spanwise per configuration.
6 Flaps per configuration.

EXAMPLE: Figures 3-84, 3-85, 3-86, 6-3, 6-4.

-EDIT-/PANEL (continued)

Description of key functions

D - DEFINE MODIFIED PANELS

Helpful in force accounting considerations. (For example, may want to strip out ramp forces due to an inlet).
Allows interference effects of panel(s) on rest of configuration, however, direct effects of such panel(s) will not be folded into aero coefficients.

Upper and/or lower surface of panel(s) may be modified ,i.e., forces from such panel(s) will not be included in aero coefficients.

Restrictions: Component must have been paneled before using D-key.
Code will recognize only the first (lowest numbered) paneled component.

Use: Follow prompts as they appear on the screen. (See figure 6-2)

P - POINT FROM CURSOR

Chordwise and spanwise coordinates are taken from the cursor position. The latter is re-assigned the value of the nearest section on the surface.

X - X LOC FROM KEYBOARD

The span location is taken as the closest section to the graphics cursor. The chordwise location is the input x-value.

C - X/C LOC FROM KEYBOARD

The span location is taken as the closest section to the graphics cursor. The chordwise location is the input x/c-value.

E - END FLAP LINE SEGMENT

E is entered following the last point for the flap hinge line being ended.

F - FINISHED FLAPLINE WORK

Entered following the entry of the endpoint of the last flap hinge line

Q - QUIT

Terminate region/paneling input and exit from EDIT/PANEL subcommand.

H - HASH LINES (EVERY 5%)

Five percent chord marks to aid flap hinge line definition.

-EDIT/PANEL- (continued)

If F is the only key (other than an H) entered, the leading and trailing edge and displayed spanwise sections will be used to define the surface regions for paneling. Flap boundaries are defined using the cross hairs and P-, X- or C-key to establish span and chord extents, respectively. The E-key indicates the end of a partial span flap hinge line. This process is demonstrated on figure 3-86.

Each region is assigned a number following the F entry as illustrated on figure 6-3. The number of spanwise panels, NSPAN, for each region is defined along the lower border of the figure and is initiated by the appearance of an arrow at the lower right. The number of chordwise panels, spacing and flap data are entered at the upper left of the figure. The following data is requested by region:

NCHRD: Number of chordwise panels for this region

NSPACE: Type of chordwise spacing:
 1- Even
 2- Half cosine
 3- Full cosine

NFLAP: Flap number for this region. A zero is entered for no flap. Otherwise use numbers between one and six. Regions having the same flap number are considered one control surface.
 Flaps should be numbered chordwise and then spanwise.
 Flap numbering specified here does not in general correspond to "D" ordering used in background analysis as may be observed using the SET/LIST c subcommand. The "D" ordering is assigned according to paneled component number ordering.

 Note: Anti-symmetric flaps must be the last "D" numbered ones in a configuration.
 If SFLAP type of BOTH is selected, it can occur only once and must be the last "D" numbered flap in the configuration.

SFLAP: Type of flap deflection (ignored if NFLAP is zero).
 -1 Anti-symmetric
 0 Both [Counts as two flaps]
 1 Symmetric

Verification of region, flap, and panel specification using the v operand is illustrated on figure 6-4 (i.e., using subcommand PAN,V in **EDIT mode).

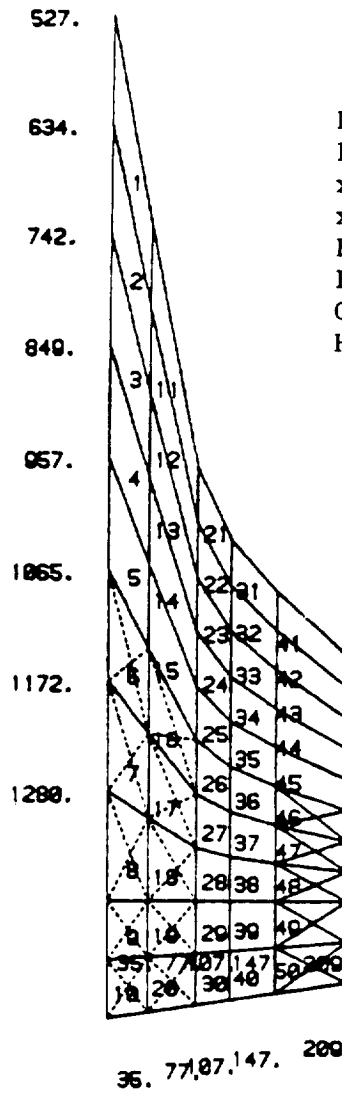
Input control surface deflections for all APAS analysis are in the streamwise direction, not perpendicular to the flap hingeline. Most wind tunnel tests deflections are perpendicular to the flap hingeline. Deflections perpendicular to the flap hingeline are calculated by $\delta(\text{streamwise}) = \delta(\text{perpendicular}) \cdot \cos(\text{sweep angle of hingeline})$

-EDIT-/PANEL (continued)

200.00 WING W/ELEVON

EDIT**
 →→→ s [3]
 SAVED IN PERM FILE.
 EDIT**

1 REPAINT VIEW-SHOWING
 PANEL MODIFICATION
 2 CONTINUE PROCESSING
 →→→ 2 [2]
 DON'T FORGET TO SAVE
 CHANGES



MENU OF KEY FUNCTIONS
 DEFINE MODIFIED PANELS : D
 POINT FROM CURSOR : P
 x LOC FROM KEYBOARD : X
 x/c LOC FROM KEYBOARD : C
 END FLAP LINE SEGMENT : E
 FINISHED FLAPLINE WORK : F
 QUIT : Q
 HASH LINES (EVERY 5%) : H

1 SELECT PANEL NO.S TO
 BE MODIFIED IN FORCE
 INTEGRATION
 2 USE PRESENT DEFINITION
 →→→ 1 [1]

MENU OF KEY FUNCTIONS
 TURN OFF UPPER PANEL : U
 TURN OFF LOWER PANEL : L
 TURN OFF PANEL : B
 TURN ON PANEL : O
 EXIT : E

Figure 6-2. Panel Modification Process with Prompts/Responses.

-EDIT-/PANEL (continued)

APAS SAMPLE SESSION GEOMETRY FILE

ENTER - NCHRD,NSPACE,NFLAP,SFLAP
 DEFAULTS - 10 , 1 , 0 , 1
 REGION 1 - 3,2,1,
 REGION 2 - 5
 REGION 3 - 3,1,2
 REGION 4 - 8,2,1
 REGION 5 - 5
 REGION 6 - 3,1,2
 REGION 7 - 8,2
 REGION 8 - 3,1,2
 REGION 9 - 8,2
 REGION 10 - 3,1,2

MENU OF KEY FUNCTIONS
 DEFINE MODIFIED PANELS: D
 POINT FROM CURSOR : P
 x LOC FROM KEYBOARD : X
 x/c LOC FROM KEYBOARD : C
 END FLAP LINE SEGMENT : E
 FINISHED FLAPLINE WORK: F
 QUIT : Q
 HASH LINES (EVERY 5%) : H

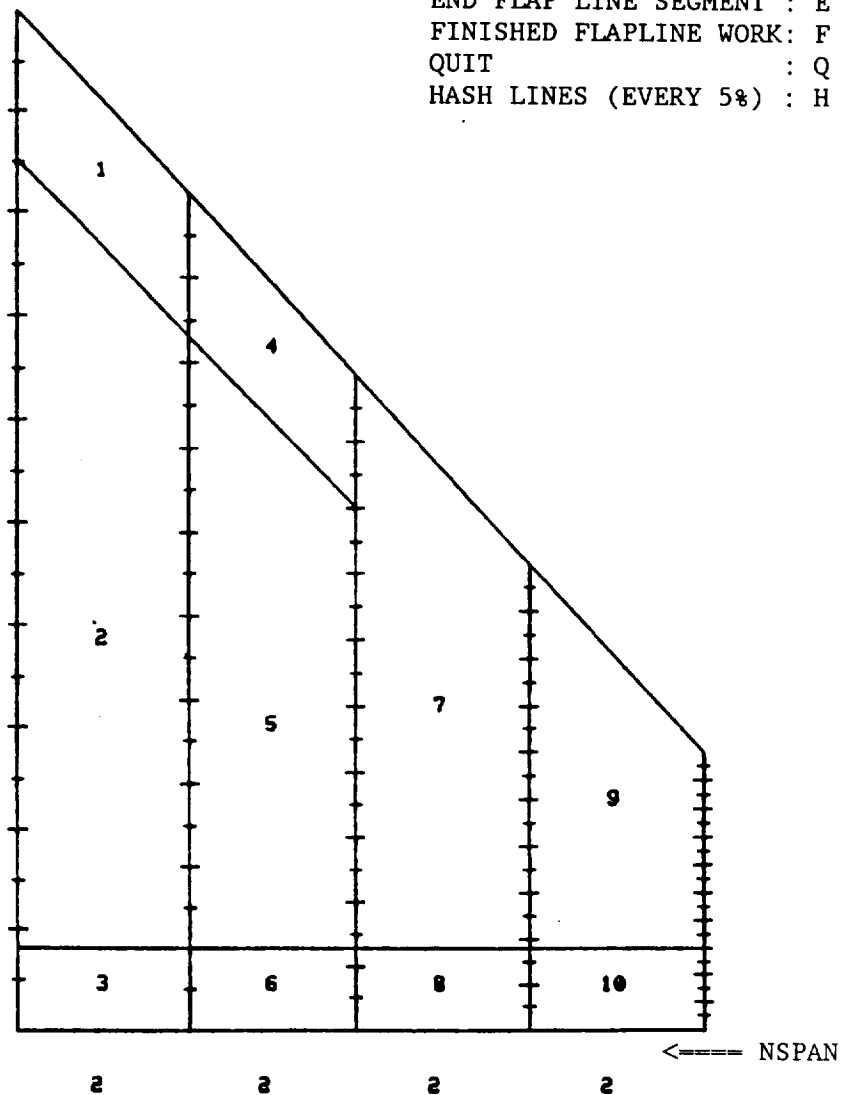


Figure 6-3. Surface Region, Paneling, and Flap Specification.

-EDIT-/PANEL (concluded)

APAS SAMPLE SESSION GEOMETRY FILE

MENU OF KEY FUNCTIONS

DEFINE MODIFIED PANELS: D
 POINT FROM CURSOR : P
 x LOC FROM KEYBOARD : X
 x/c LOC FROM KEYBOARD : C
 END FLAP LINE SEGMENT : E
 FINISHED FLAPLINE WORK: F
 QUIT : Q
 HASH LINES (EVERY 5%) : H

REGION LEGEND

REGION, FLAP(NCHRD, NSPAN)
 SFLAP, SPACING

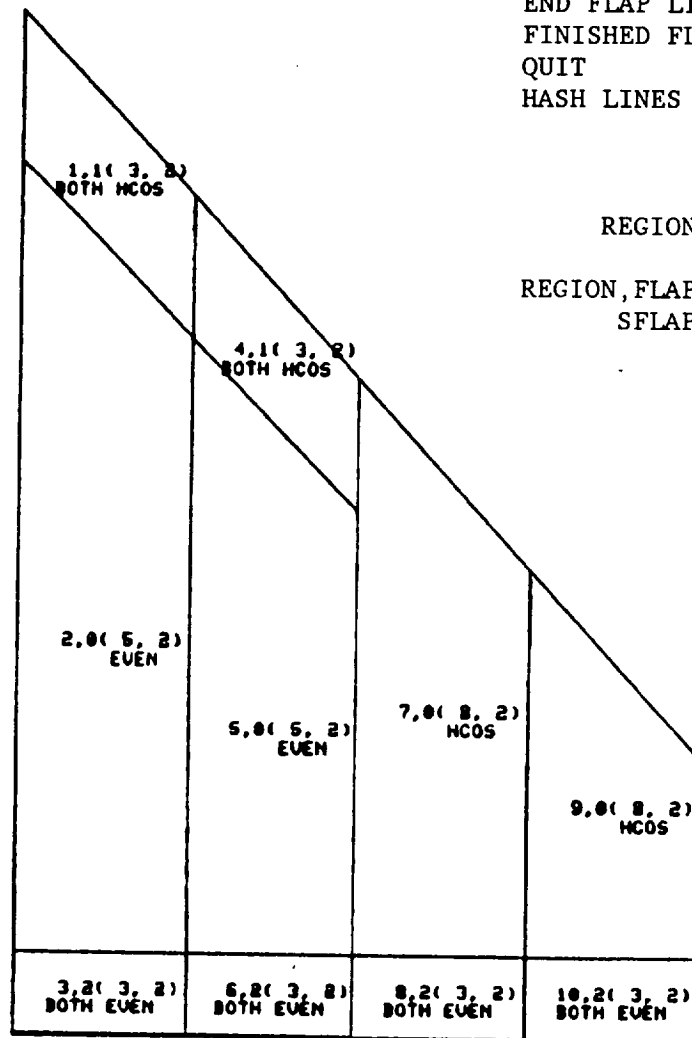


Figure 6-4. Verification of Surface Region, Paneling, and Flap Specifications.

-EDIT-/PARAMETER

SUBCOMMAND: PARAMETER

PARAMETER

OPERANDS: None.

ABBREVIATION: P

FUNCTION: Change component parameters contained in the header and record of each component.

PROMPTS/RESPONSES:

```
100.0     DEMO COMPONENT
TYPE: 1
NWET: 1 1 -1 1                   [-1 means this segment will be unwetted]
ENTER TYPE:
→→→ 2   [or <CR> to retain]

ENTER NWET:
→→→ 1,-1,-1,1   [or <CR> to retain]

COMPONENT SYMMETRY: REFLECTIVE AND SYMMETRIC
ENTER:       1 : NON-REFLECTIVE
             2 : REFLECTIVE
             POSITIVE : ASYMMETRIC
             NEGATIVE : SYMMETRIC
CARRIAGE RETURN: UNCHANGED
→→→ 1   [or <CR> to retain]

XO:    0.00 YO:   40.00 ZO -20.00
ENTER NEW VALUES, PLACE COMMA TO LEAVE VALUE UNCHANGED
→→→ 200.0,, -30   [or <CR> to retain]

BET:   0.00 ALP:   0.00 GAM:   0.00
ENTER NEW VALUES, PLACE COMMA TO LEAVE VALUE UNCHANGED
→→→ ,,10.   [or <CR> to retain]

EDIT**
```

EXAMPLE: Figure 3-36.

-EDIT-/PARAMETER (concluded)

The NWET variable has been expanded in it's definition to allow definition of emissivity coefficient and invoke the Mangler transformation. The following convention now applies.

- | | |
|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| -99 to -02 | Mangler transformation invoked. Skin Friction is calculated as conical surface. Emissivity coefficient is the absolute value of NWET divided by 100 i.e. 0.99 to 0.02 |
| -1 | Segment not included in force summation (original definition) |
| 1 | Segment included in force summation. Emissivity is 0.85(default original definition). |
| +02 to +99 | Segment included in force summation. Skin friction calculated as flat plate. Emissivity coefficient is the value of NWET divided by 100 i.e. 0.02 to 0.99. |

-EDIT-/RESECT

SUBCOMMAND: RESECT

RESECT

OPERANDS: None.

ABBREVIATION: None.

FUNCTION: Allow the redefinition of the spanwise order from root thru tip to tip thru root of type 3 or 4 components. Used to reorder symmetric (semi-span defined) geometry into asymmetric geometry definition. Afterwards scale the defining geometry by $Y=-1.0$ for type 3 components. Reflects airfoil about X-Z plane for type 4 components.

-EDIT-/SAVE

SUBCOMMAND: SAVE

SAVE[,COMPN][,FILE]

OPERANDS: COMPN - New component number; Default is current number.
 FILE - [P]ERMANENT; Default.
 [L]OCAL

ABBREVIATION: S

FUNCTION: Save work performed on a component in edit.

EXAMPLE: Figures 3-20, 3-24, 3-33, 3-36, 3-40, 3-79, 3-82.

SUBCOMMAND: SC

SC=VAL,[1,NS][,V]

OPERANDS: VAL - Scaling value.
(Must be preceded by an '=' sign)

1 - First component section.

NS - Number of component sections.

V - Verify with printout of scaled points.
Default suppresses printout of scaled points.

ABBREVIATION: None.

FUNCTION: Full component scaling relative to component origin.

Can be used in conjunction with subcommands DX,DY,DZ to scale and translate along more than one axis.

Also see subcommands SX,SY,SZ,ST for specialized component scaling.

EXAMPLE: SC=0.10,1,5,V

-EDIT-/SEG

SUBCOMMAND: SEG



SEG

OPERANDS: Menu Driven.

ABBREVIATION: None.

FUNCTION: Allow the alteration of the segmentation of type 1 and 2 Components (must be used in conjunction with PADD and PDEL subcommands near "Triple Points").

Note: Changes must be saved before exiting EDIT.

OPTIONS:

- 1 - graphical presentation of a typical section. (requested by user).
- 2 - specification of point number at segment.
- 3 - END (return to EDIT mode).

SUB-OPTIONS (graphically only)

MOVE - Select an existing segment and reposition it to a new location (at an existing point.) Requires two separate cross-hairs inputs.

ADD - Add an additional segment definition graphically with screen cross-hairs or by point specification.

DELETE - Remove a segment edge definition.

REPAINT - Display the specified section as currently modified.

END - Return the user to EDIT mode.

EXAMPLES: 178,179 and 180

EDIT 104

** EDIT**

→→→ SEG

ENTER 1 FOR SEGMENT SPECIFICATION
 2 FOR GRAPHIC SEGMENT REPRESENTATION
 3 TO EXIT

→→→ 1

ENTER THE REPRESENTATIVE SECTION YOU WISH TO WORK WITH

→→→ 2

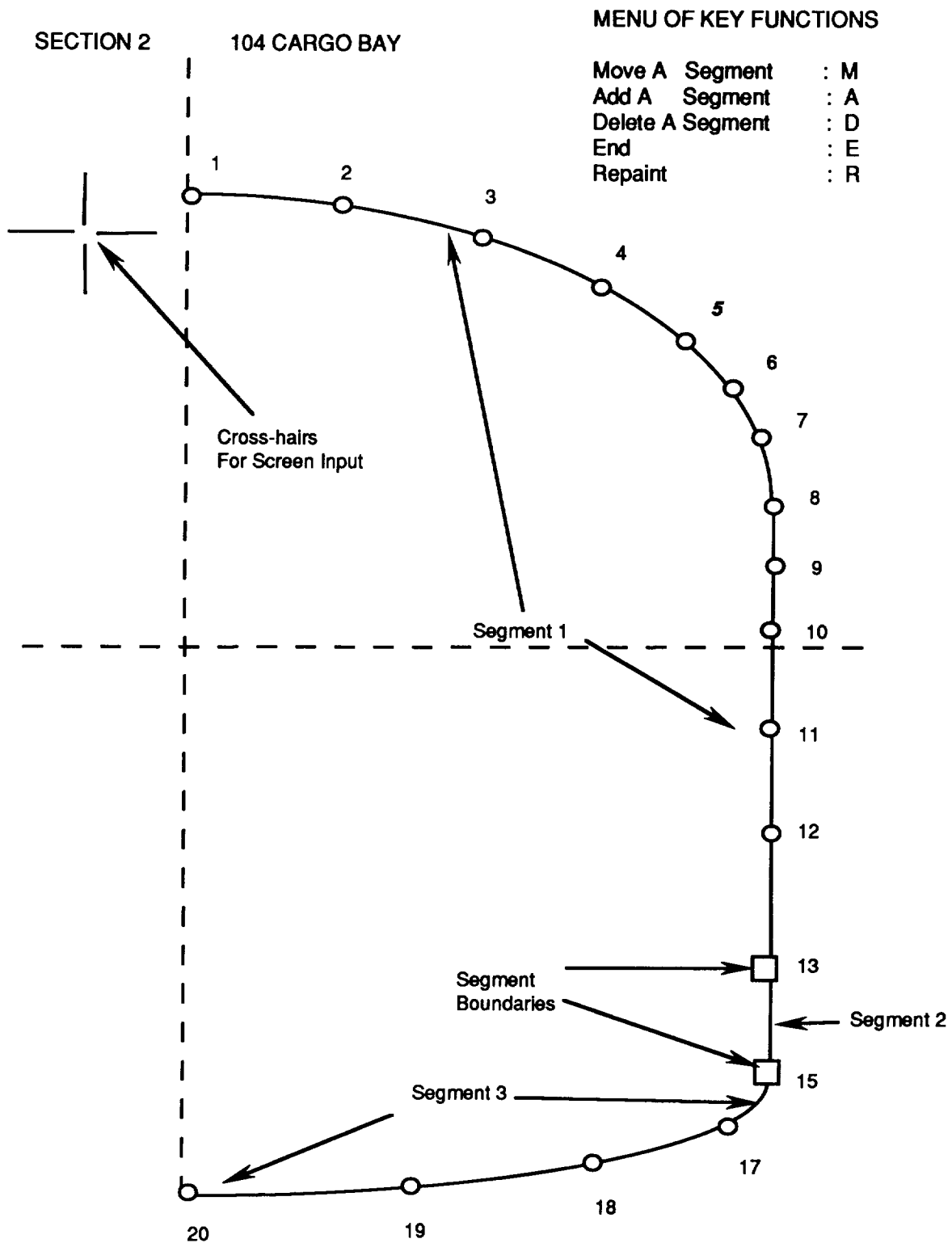
POINT LOCATION OF SEGMENTS

→→→ 13 15

ENTER UPPER CASE LETTER

M TO MOVE A SEGMENT
A ADD A SEGMENT
D DELETE A SEGMENT
E END
R RELIST SEGMENT

Example SEG command menus for Numerical segment Specification



SEG Command menus for Graphic Segment Specification

-EDIT- /SPON,SDON

SUBCOMMAND: SPON, SDON

SPON or SDON

OPERANDS: None.

ABBREVIATION: None.

FUNCTION: Change print and display defaults.
Can also be used in conjunction with LIST subcommand.

SPON	Suppress print
SDON	Suppress display

EXAMPLE: SPON
1,L,SPON (When used in conjunction with LIST subcommand)

-EDIT-/SX,SY,SZ,ST

SUBCOMMAND: SX, SY, SZ, ST

[SEC,]S*=VAL[,PNT1,PNT2][,V]
 *-X or Y or Z or T
or,
S*=VAL[,SEC1,SEC2][,ALL][,V]

OPERANDS: SEC - Section number, Default is current section.

VAL - Scaling value.
(Must be preceded by an "=" sign)

PNT1,PNT2 - Scale only *-points from PNT1 to PNT2.
Default (no entry) scales all *-points in section.

V - Verify with printout of scaled *-points.
Default suppresses printout of scaled *-points.

In second form of command the following additional operands are used.

SEC1,SEC2 - Scale only *-points in sections SEC1 to SEC2.

ALL - Scale all *-points in each section.

ABBREVIATION: None.

FUNCTION: Provide single axis scaling capability.

SX - Scale x-coordinates
SY - Scale y-coordinates
SZ - Scale z-coordinates
ST - Scale wing sections to thickness specified by VAL

Can be concatenated with each other and subcommands DX, DY,
and DZ to scale and translate along more than one axis.

EXAMPLES: 1,SX=0.5 [Scales X-points (all) in section 1 by 0.5]
3,SZ=0.5,1,11,V [Scales Z-points from 1-11 in sect 3 by 0.5]
or,
SX=0.5,3,5,ALL [Scales ALL X-points in sections 3-5 by 0.5]

-EDIT-/T/C

SUBCOMMAND: T/C

[SEC,]T/C

OPERANDS: SEC - Section number; Default is current section.

ABBREVIATION: T

FUNCTION: Evaluates and displays maximum T/C and associated x/c.

EXAMPLE: 1,T

-EDIT-/VIEW

SUBCOMMAND: VIEW

VIEW[-YAW,PITCH,ROLL]

OPERANDS: YAW,PITCH,ROLL - Optional angles, in degrees, for TYPE 1 through 4 component visual editing. (Must be preceded by an "-" sign)

Defaults are:

(0.0, 0.0,0.0) for TYPES 1 and 2
(90.0,-90.0,0.0) for TYPES 3 and 4

ABBREVIATION: VI

FUNCTION: Component editing using graphical display.

OPERATION: Component(s) being edited will be displayed on the screen. User specified subsidiary components are shown as dashed lines. Additional input for this subcommand is through the graphics cursor using keys to define the type of operation desired. Key definition is provided in the accompanying menu.

Caution: It is best to use menu operations with default view angles only.

EXAMPLE: Figures 3-16 through 3-19, 3-21 through 3-25, 3-39, 3-40, 3-74 through 3-82.

MENU AND KEY DEFINITIONS:

- I - Insert a section at the cursor x-location using second-order interpolation.
- F - Insert a section at the cursor x-location using linear interpolation.
- D - Delete closest section to cursor x-location.
- T - Scale section indicated by graphics cursor such that the top of the section matches the z-(vertical) location of the cursor. Scaling is on z only. The bottom of the section is unchanged.
- B - Scale section indicated by graphics cursor such that the bottom of the section matches the z-(vertical) location of the cursor. Scaling is on z only. The top of the section is unchanged.
- U - Move section nearest cursor vertically such that the top of the section matches the z-(vertical) location of the cursor.
- L - Move section nearest cursor vertically such that the bottom of the section matches the z-(vertical) location of the cursor.
- O - Display the edited component on the present screen.
- R - Repaint the screen.
- Z - Zoom in on an area. This input locates one corner of the box; the next input from the cursor locates the opposite corner.
- W - Increases the viewing area by 100%.
- E - End.

The various key options are accomplished in one operation, one section at a time with the exception of zoom. Keys D,T,B,U, and L operate on the section closest to the cursor at the time the key is entered. Keys I and F do not function near existing sections.

-EDIT-/VON,VOFF

SUBCOMMAND: VON,VOFF

VON or VOFF

OPERANDS: None.

ABBREVIATION: None.

FUNCTION: Activates verify mode during EDIT to automatically print changes.

EXAMPLE: VON

-EDIT-/X,Y,Z

SUBCOMMAND: X,Y,Z

[SEC,]*[-VAL][,N1][,N2][,N3][,V]
*-X or Y or Z

OPERANDS:

- SEC - Section number; Default is current section.
- VAL - Value to replace * (* = x or y or z).
(Must be preceded by an "=" sign)
- N1 - Point to be given new value.
- N2 - All points from N1 to N2 are to be set to VAL.
- N3 - All points from N1 to N2 are to be set to the
value of point N3.
Default is "ALL". (When N1, N2, or N3 are omitted)
- V - Verify input value.

ABBREVIATION: None.

FUNCTION: Replace present values of x, y, or z of a given section using
subcommand X, Y, OR Z respectively.

EXAMPLE: Figures 3-30, 3-31, 3-33.

-EDIT-/XH

SUBCOMMAND: XH

XH[,N1][,N2]

OPERANDS: N1 - Change point N1 to y,z-values indicated by cross hairs.
N2 - Change points from N1 to N2 to y,z-values indicated by cross hairs.
Default - locate point to modify and hit spacebar.
Next, move cross hairs to desired new location.
Hit spacebar to fix point and to continue.
Otherwise enter zero to fix point and to end cross hairs mode.

ABBREVIATION: None.

FUNCTION: Cross-section modification using graphics cursor.
Valid for TYPES 1,2,7 and 8.

EXAMPLE: Figure 3-27.

-EXIT-

COMMAND: EXIT



EXIT

OPERANDS: None.

ABBREVIATION: EX

FUNCTION: Close files and exit from system.

EXAMPLE: **OK**
 →→→ EXIT

-FILES-

COMMAND: FILES

FILES[,FILE]

OPERANDS: FILE - [P]ERMANENT; Default.
[L]OCAL
[C]OMPONENT

ABBREVIATION: FILE

FUNCTION: List components stored in either permanent or indicated file.

EXAMPLE: Figures 3-69, 3-74, 3-82, 4-1, 4-11.

-FLAT-

COMMAND: FLAT

FLAT,COMP(1)[,COMP(2),...COMP(N)]

OPERANDS: COMP(N) - Component(s) to be used for reference.
At least one must be specified.

ABBREVIATION: None.

FUNCTION: Construct a flat plate surface (TYPE=4) component, using reference component(s) as a guide.
Helpful in creating subsonic-supersonic analysis model to represent a flat plate wind tunnel model of a configuration.

LIMITS: The leading and trailing edge region of interest must be represented by a single component. For example, a fuselage is typically composed of several components. FLAT cannot use them, but it could use a slender body component (which is a single component that represents the entire fuselage).

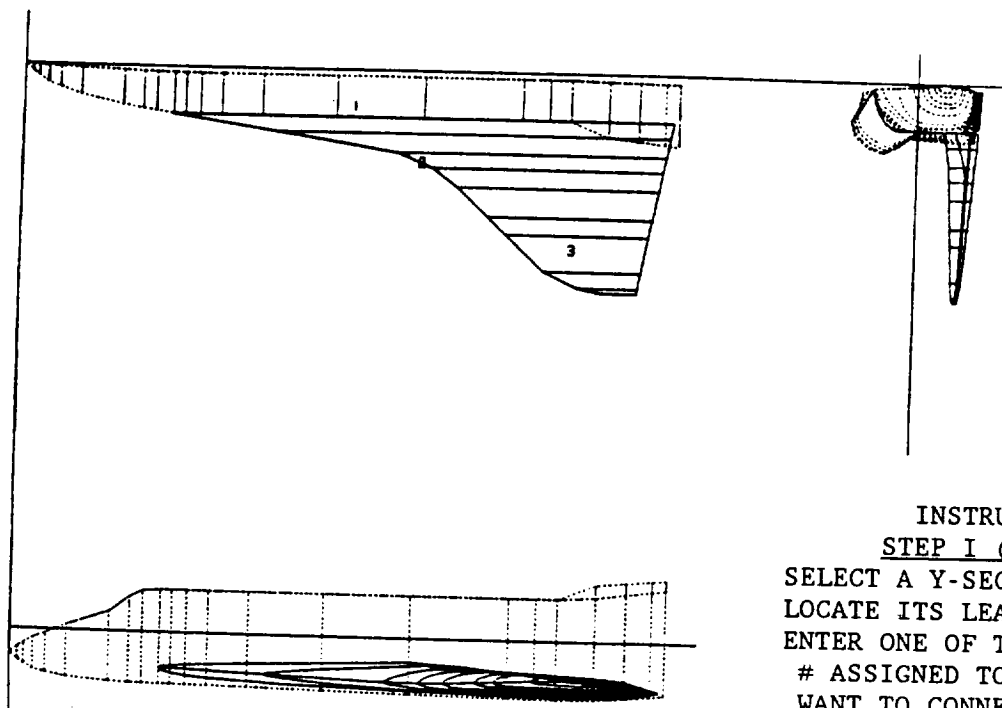
EXAMPLE:

PROMPT/RESPONSE:

```
+++ flat 611 121
    ENTER COMPONENT NUMBER: [for flat plate component being created]
+++ 999
    ENTER COMPONENT NAME:
+++ Shut Flat Plate
```

[Screen clears and following image is presented]

-FLAT- (continued)



INSTRUCTIONS

STEP I (PLANVIEW)

SELECT A Y-SECTION AND
LOCATE ITS LEADING EDGE.

ENTER ONE OF THE FOLLOWING:

ASSIGNED TO COMPONENT YOU
WANT TO CONNECT WITH (1 2 ?)

0 FOR A FREE LINE.

SPACEBAR TO INDICATE WORK
ON COMPONENT IS COMPLETED.

STEP II (SIDE VIEW)

SELECT A Z-LEVEL.

LOCATE TRAILING EDGE.

PRESS SPACEBAR.

REPEAT ABOVE AS REQUIRED.

-FLAT- (concluded)

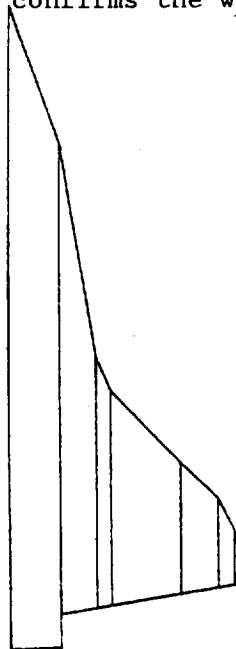
The objective is to make a flat plate model with a planview like that shown on previous page. Following the instructions listed, the cross hairs are first located at the L.E. centerline of the planview and the 1-key is entered. The one (1) -key represents component 1 as listed in the figure. Next the cross hairs are moved to the side view and the z-level is located at the nose. The cross hairs are then moved to the trailing edge of this component and the spacebar is pressed. The next section to be defined for the flat plate model is where the wing joins the body. Thus, the cross hairs are moved to the planview body-wing leading edge juncture and 1-key is entered. This is followed by moving the cross hairs to the side view and locating the z-level at the leading edge of the root section of the wing. Holding that z-level the cross hairs are then moved aft to the trailing edge of component number 1 (=611=slender body), and the spacebar is pressed.

Another section is defined where the wing joins the body, but this time the 2-key is entered and the T.E. is on the wing component. The user then moves outboard along the span, defining as many sections for the flat plate model as desired.

The process is ended by pressing the spacebar in the planview prompting cycle. The screen erases and the following message appears:

```
**OK**  
BE SURE TO CATALOG COMPONENT IF YOU WANT TO KEEP IT  
**OK**  
--- cata  
**OK**
```

The flat plate component (999) may then be examined using EDIT/VIEW. The resulting view is shown below, and confirms the work done in FLAT.



Shuttle Flat Plate Model using EDIT/VIEW Command

- INTERFERENCE -

COMMAND: INTERFERENCE

INTERFERENCE,COMP(1)[,COMP(2),...COMP(N)[,FILE]

OPERANDS: COMP - Component number(s) to be used for reference.
At least one must be specified.

FILE - [P]ERMANENT; Default.
[L]OCAL
[B]OTH

ABBREVIATION: INTE

FUNCTION: Slender body interference shell construction for subsonic/supersonic analysis. Shell purpose is to accomodate any interference effects from other components so that the no normal flow boundary condition of the slender body to which it is attached is maintained. The surrounding interference effects are integral (averaged), thus panel density on the shell is not real important. In fact the shell may exist inside the slender body in places with no ill analysis effect.

Must use CATALOG command for file storage.

Must be numbered within the same decade of the slender body component it is to accompany in the analysis mode.

Must be paneled to have at least three (3) chordwise panels.

EXAMPLE: Figure 3-83.

-JETF-

COMMAND: JETF

JETF,COMP(1)[,COMP(2),...COMP(N)]

OPERANDS: COMP(N) - Component(s) to be used for reference.
At least one must be specified.

ABBREVIATION: None.

FUNCTION: Construct a jet flap (TYPE=6) component, using reference component(s) as a guide.
Required component type for simulating vortex sheet for a trailing edge jet flap.

Must use CATALOG command for file storage.

LIMITS: Only one jet flap component per configuration.

Jet flap component must follow all other configuration panels ,i.e., must be highest numbered paneled component.

Do not use even spacing when paneling this component. Half cosine is recommended and cosine spacing for paneled component upstream.

EXAMPLE:

PROMPT/RESPONSE:

```
→→→ jetf 3100           [3100 is wing from NASA TN D-8361]
      ENTER COMPONENT NUMBER: [for jet flap component being created]
→→→ 3200
      ENTER COMPONENT NAME:
→→→ jetflap for 3100
```

[Screen clears and following image is presented]

JETFLAP CONSTRUCTION SAMPLE

* ENTER	JET LENGTH IN CHORD LENGTHS: 2
	1
* ENTER	JET LENGTH IN CHORD LENGTHS: 2

INSTRUCTIONS

STEP I (PLANVIEW)

SELECT A Y-SECTION AND
LOCATE ITS LEADING EDGE.
ENTER ONE OF THE FOLLOWING:
ASSIGNED TO COMPONENT YOU
WANT TO CONNECT WITH (1 2 ?)

0 FOR A FREE LINE.

SPACEBAR TO INDICATE WORK
ON COMPONENT IS COMPLETED.

STEP II (SIDE VIEW)

SELECT A Z-LEVEL.
LOCATE TRAILING EDGE.
PRESS SPACEBAR.

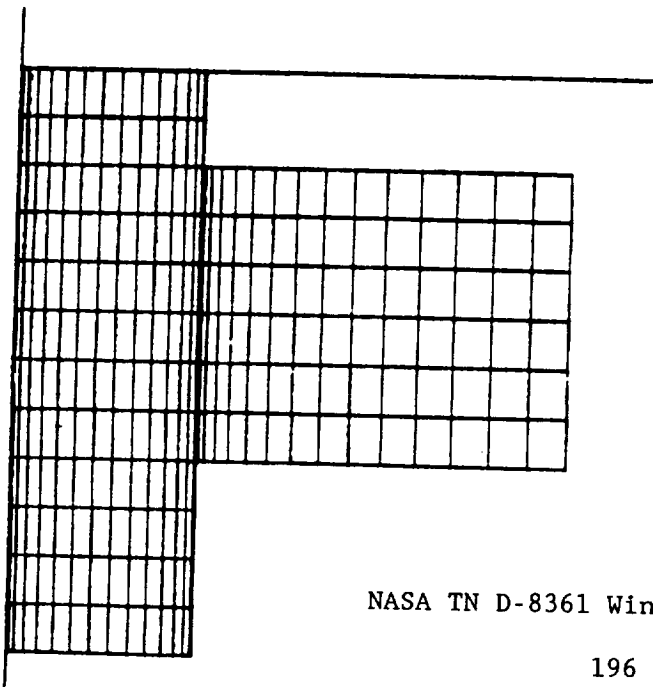
REPEAT ABOVE AS REQUIRED.

-JETF- (continued)

The objective is to create a jet flap component whose leading edge will coincide with the trailing edge of the reference component(s). The spanwise extent of the jet flap is controlled by the user and as can be seen in the planview portion on the previous page. This was accomplished by following the instructions listed in the right corner. The cross hairs were first located at the L.E. and part way outboard along the span ($\eta \approx .1$) of the planview and the 1-key is entered. The one (1) -key represents component 1 as listed in the figure. Next the cross hairs are moved to the side view and the z-level is located. The cross hairs are then moved to the trailing edge of component one (-3100) and the spacebar is pressed. The program responds by drawing the inboard horizontal line shown in the planview and prompts the user to enter the jet flap component chord length desired for this first section in terms of the chord of the parent component (one). The user requests two chord lengths. This process is repeated for an outboard section for the jet flap. The process is ended by pressing the spacebar in the planview prompting cycle. The screen erases and the following message appears:

```
      **OK**
BE SURE TO CATALOG COMPONENT IF YOU WANT TO KEEP IT
      **OK**
->>> cata
      **OK**
```

The jet flap component (3200) and the parent component (3100) are then paneled using the EDIT/PANEL command. Cosine spacing is used for 3100 and half cosine spacing for 3200. Do not use even spacing, as a poor simulation will result. Also, the leading edge panel spacing of the jet flap must mirror the trailing edge (and going forward panel spacing) of the parent component (3100). The view shown below is from the configuration verify mode of the SET command, and confirms the work done in JETF and EDIT/PANEL.



CONFIGURATION: 2

SREF: 2400.00

SPAN: 120.000

CBAR: 20.0000

XCG : 30.0000

YCG : .0

ZCG : .0

270 PANELS

18 SECTIONS

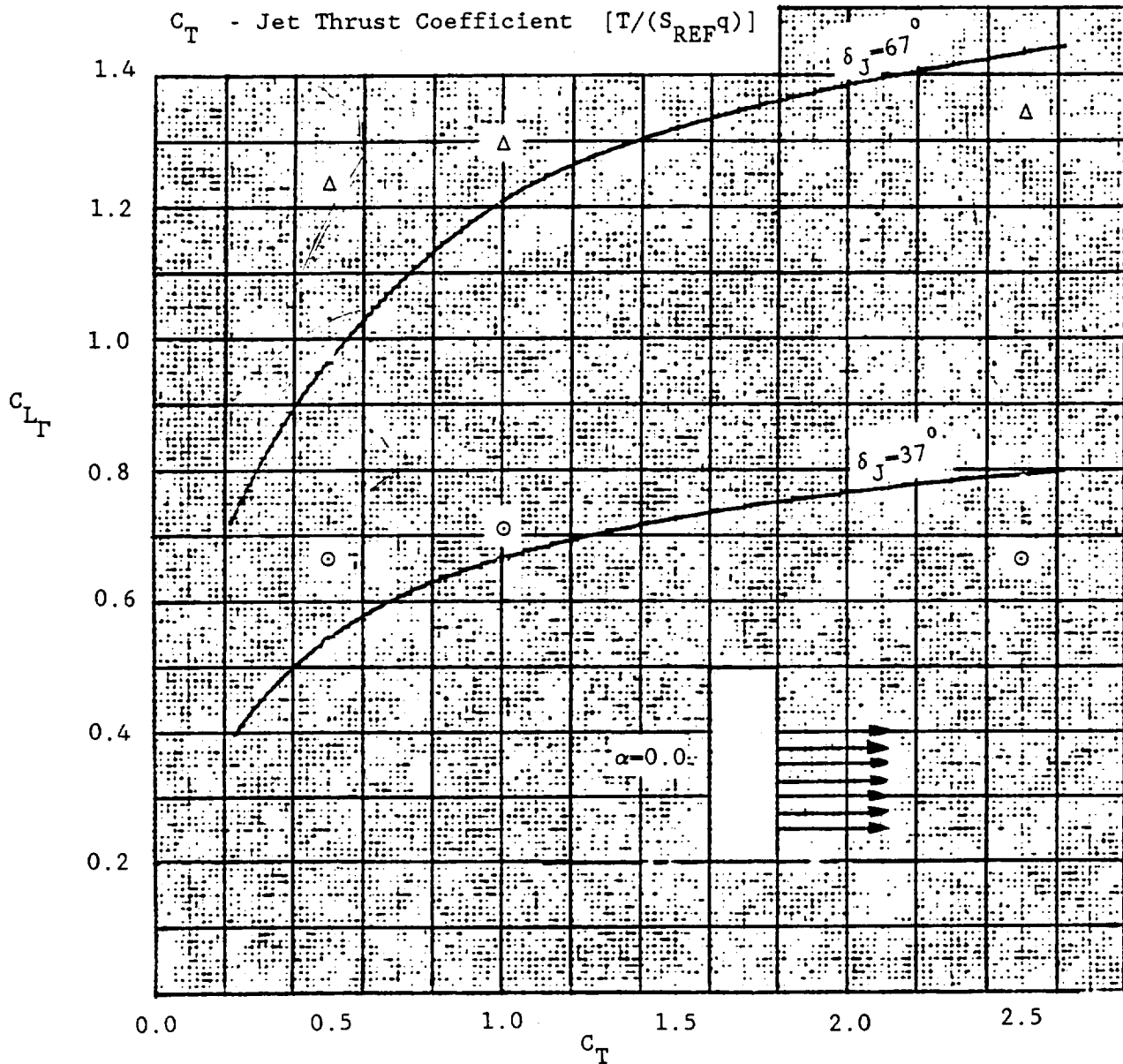
NASA TN D-8361 Wing with Jet Flap Component

-JETF- (concluded)

APAS comparison with wind tunnel results for the NASA TN D-8361 jet flap wing are shown below.

C_{L_T} - Lift coefficient neglecting jet momentum forces (circulation lift)

C_T - Jet Thrust Coefficient $[T/(S_{REF}q)]$



— APAS

\circ 37 degree initial jet deflection angle
 Δ 67 degree initial jet deflection angle

} Test Data Ref. 10

Test data corrected for thickness by $(1+t/c)^{-1}$

- PANBDY -

COMMAND: PANBDY

PANBDY,COMP(1)[,COMP(2),...COMP(16)][,FILE]

OPERANDS: COMP - Component(s) needed to form a paneled body component.
Limit is sixteen (16).
Component numbers must be in same decade (non cardinal
o.k.) and numbered according to increasing x.
Do not overlap components.

FILE - [P]ERMANENT; Default.
[L]OCAL
[C]OMPONENT

ABBREVIATION: None

FUNCTION: Paneled body construction.
Typically used to represent the fuselage.
Used in subsonic analysis mode only.

Must use CATALOG command to store on file of choice.

LIMITS: One (1) paneled body component per configuration.

Maximum number of sections: (total for all geometry components
to be used in forming a paneled body component)
Twenty five (25) for TYPE 10 paneled body (symmetric).
Sixteen (16) for TYPE 11 paneled body (asymmetric).

PROMPT/RESPONSE:

→→→ PANBDY 11,12,13,14

PANELED BODY CONSTRUCTION
ENTER COMPONENT NUMBER

→→→ 150

INPUT COMPONENT NAME

→→→ PANELED SHUT

INPUT - NUMBER OF POINTS PER SECTION

Note: Existing Geometry uses 10 points/section
Typical Panel Density is 15 points/section

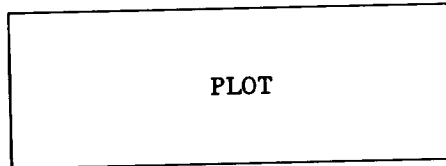
→→→ 15

BASE CENTROID: X,Y,Z = 1516.7971 0.0000 -0.6865
BASE AREA : 52367.0400

DON'T FORGET TO ENTER THE COMMAND: CATALOG
IF YOU WANT TO SAVE PANBDY COMPONENT CONSTRUCTION

-PLOT-

COMMAND: PLOT



OPERANDS: None.

ABBREVIATION: None.

FUNCTION: Analysis display.
The available variables are presented on Table 8.

EXAMPLE: Figures 5-16 through 5-37.

-PLOT- (continued)

Table 8. Analysis Plot Variables.

A	Angle of attack, α , degrees
B	Sideslip angle, β , degrees
CD	Total drag coefficient, C_D
CDO	Drag coefficient at $C_L = 0.0$, C_{D_0}
CD0	Zero suction drag coefficient, $C_{D_{0\%}}$
CDM	Wave drag coefficient, C_{D_W}
CDP	Viscous drag coefficient, C_{D_P}
CD100	100% Suction drag coefficient, $C_{D_{100\%}}$
CL,CLLIN	Lift coefficient, C_L
CLA,CLALIN	Lift curve slope, C_{L_α} , deg^{-1}
CLO	Lift coefficient at zero angle of attack, C_{L_0}
CM,CMLIN	Pitching moment coefficient, C_M
CMA,CMALIN	Pitching moment slope, C_{M_α} , deg^{-1}
CN,CNLIN	Yawing moment coefficient, C_n
CNA	Normal force slope, C_{N_α} , deg^{-1}
CNB,CNBLIN	Yawing moment slope, C_{n_β} , deg^{-1}
CNR	Normal force coefficient, C_N

-PLOT- (concluded)

Table 8. Analysis Plot Variables (concluded).

CP	Upper and Lower surface C_p versus x/c
CPNET	(Lower-Upper) C_p versus x/c
CPL	Lower surface C_p versus x/c
CPU	Upper surface C_p versus x/c
CR,CRLIN	Rolling moment coefficient, C_ℓ
CRB,CRBLIN	Rolling moment slope, $C_{\ell\beta}$, deg^{-1}
CY,CYLIN	Side force coefficient, C_Y
CYB,CYBLIN	Side force slope, $C_{Y\beta}$, deg^{-1}
DCMDCL	Pitch stability dC_M/dC_L
LOD	Lift divided by Drag, C_L/C_D
M	Mach number
P	Roll rate, rad/sec
Q	Pitch rate, rad/sec
R	Yaw rate, rad/sec

-PLOT-/END

SUBCOMMAND: END



END

OPERANDS: None .

ABBREVIATION: E

FUNCTION: Ends plotting activity of PLOT and returns the user to the
 OK mode.

-PLOT-/LIST

SUBCOMMAND: LIST



LIST

OPERANDS: None.

ABBREVIATION: L

FUNCTION: Provides list of runs currently available in the output file.

EXAMPLE: Figure 5-16.

-PLOT-/PLOT

SUBCOMMAND: PLOT

```
PLOT[n] [Gg1] [[,FUNCTION1[(IC1=val,...,ICn=val)]]],...
[[Gg3] [[,FUNCTION3[(IC1=val,...,ICn=val)]]] [,FORMf]
[[RUN(R1,R2,...Rk)] [,MACH (M1,M2,...Mk)]
[[,SOG=VAL] [,SAG=VAL] [,TOL=VAL]]
[,RUNM (N1,N2,...N1] [PAGE=p]
[,LVFIX=VNAME] [,RVFIX=NAME]
```

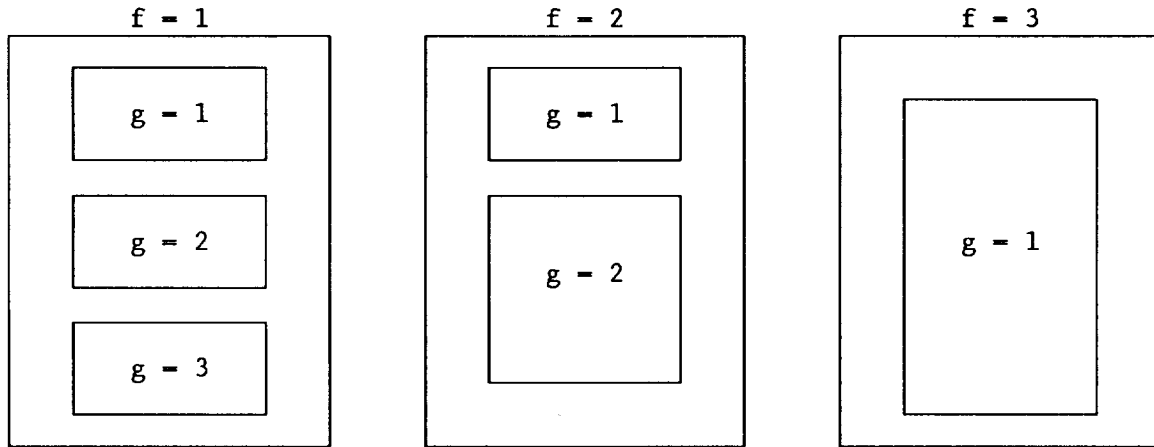
OPERANDS:

- n - SET number to concatenate onto plot list ($n \leq 12$).
(See PLOT/SET subcommand for SET number origin)
- Gg - Allows data to be arbitrarily placed on different grids of a plot form, where "g" defines the grid the FUNCTION that follows is to be placed. The default is to fill the top grid with the first function and lower grids in succession.
- FUNCTION_i - Parameters to display. For example CL/A ,i.e., lift coefficient versus angle of attack. /is used to separate the ordinate (left side) from the abscissa. If no abscissa is indicated MACH number is assumed.

IC₁=val,...initial conditions. For example CL/A/M(A=0) ,i.e., lift curve slope at zero angle of attack versus MACH number. See Table 8.

-PLOT-/PLOT (continued)

FORM [Ff] - Plot form.



RUN(R_1, R_2, \dots, R_k) - Run number list to be used for this plot ($k \leq 32$).
If a list is not supplied, the current RUN list at the time of execution will be used or may be added in the PLOT subcommand to override the SET run list. A RUN list supersedes a MACH list.

MACH(M_1, M_2, \dots, M_k)- Mach list to be used for this plot ($k \leq 32$).
Entering the mach number alone will override the current RUN list for the current MACH list. Adding a MACH list in the plot subcommand will override listings in SET command.

SOg=VAL - Ordinate grid scale, where g indicates the grid number and VAL is the numerical value of the scaling. Default (VAL = 0.0 for automatic scaling).

SAg=VAL - Abscissa grid scale, where g indicates the grid number and VAL is the numerical value of the scaling. Default (VAL = 0.0 for automatic scaling).

TOL=VAL - Comparison tolerance, where VAL equals the increment to be used when comparing initial conditions of one run against another for display consistence. Default (VAL = 0.50).

RUNM(N_1, N_2, \dots, N_n)- Run list partitioning for plotting identification.
See figures 5-27, 5-29.

$$N_1 + N_2 + \dots N_n = k \quad (n \leq 8)$$

Where k is the total number of runs in the current runlist. It is recommended that LVFIX be specified. RUNM must be set for each new plot.

-PLOT-/PLOT (concluded)

PAGE=p

- Pre-plot summary page control.

p = -1 Don't stop before plotting; Default.
0 Always stop before plotting
1 Stop only in case of error
2 Stop and make a hard copy

LVFIX=VNAME

- Independent variable VNAME to display in plot symbol table. If unspecified the first two runs are compared and the first unequal independent variable found will be used. Mach number is displayed when no differences are found. See figures 5-19 AND 5-31.

RVFIX=VNAME

- For plots using a MACH list only. Only runs with variable name VNAME as the independent variable will be selected for plotting.

ABBREVIATION: PL

FUNCTION:

Display analysis results in graphical form. Each plot is constructed independently using RUN lists or MACH lists supplied by the user. Each grid in a display can have different initial conditions.

The required input can be reduced by pre-entering common sets of display parameters using the SET subcommand.

EXAMPLE:

Figure 5-18.

-PLOT-/SET

SUBCOMMAND: SET

```
SET[n] [Gg1] [[,FUNCTION1[(IC1-val,...,ICn-val)]]],...  
[[Gg3] [,FUNCTION3[(IC1-val,...,ICn-val)]]] [,FORMf]  
[[RUN(R1,R2,...,Rk)] [,MACH (M1,M2,...,Mk)]]  
[[,SOG-VAL] [,SAG-VAL] [,TOL-VAL]]  
[,RUNM (N1,N2,...,N1)] [PAGE-p]  
[,LVFIX-VNAME] [,RVFIX-NAME]
```

OPERANDS:

- n - SET number assigned to this input line ($n \leq 12$).
- .
- .
- Same as PLOT subcommand.
- .

ABBREVIATION: None.

FUNCTION: Used to define and display plot lists (schedules) which are used on a regular basis. A schedule is accessed from the PLOT subcommand by concatenating it. See figure 5-27.

SET is a convenience function in APAS. RUN lists are not usually placed on PLOT lists since they are the most varied operand entered in the PLOT command statement.

EXAMPLE: Figures 5-20, 5-27

-RENAME-

COMMAND: RENAME

RENAME,COMP[,FILE]

OPERANDS: COMP - Component number.
FILE - [P]ERMANENT; Default.
[L]OCAL

ABBREVIATION: RENA

FUNCTION: Change component name.

EXAMPLE: rename,121
ENTER NEW COMPONENT NAME
+++ wing

-RENUMBER-

COMMAND: RENUMBER

RENUMBER, OLDCOMPN, NEWCOMPN[, FILE]

OPERANDS: OLDCOMPN - Old component number.
NEWCOMPN - New component number.
FILE - [P]ERMANENT; Default.
[L]OCAL

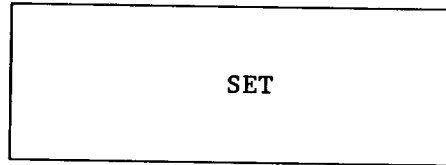
ABBREVIATION: RENU

FUNCTION: Change component number.

EXAMPLE: RENU,101,121

-SET-

COMMAND: SET



OPERANDS: None.

ABBREVIATION: None.

FUNCTION: Provides input file definition for background analysis in UDP and/or HABP.

Process:

- (1) Define configuration (ATTACH components to LOCAL file).
 - (2) Enter SET command and define reference quantities for this configuration when prompted.
 - (3) Define run schedule, setting appropriate parameters, to be submitted to background analysis as input file.
- Note: Some parameters, such as mach, alt etc., are set on the run# card. Others are set in response to the UDP or HABP analysis options menus.

A configuration does not have to be ATTACHED to the LOCAL file before entering the SET command if that configuration already exists within the SET environment.

Use the CLEAR command to remove all components from LOCAL file if a new configuration is not to be created when entering the SET command.

LIMITS:

- 10 Configurations
- 15 Analysis Components/Configuration
 - Analysis Components are: Slender Body, Interference Shell, Surfaces and Field Points.
 - Slender Body + Interference Shell counts as one analysis component.
 - Field Points count as one analysis component per 25 points.
- 70 Component Sections/Configuration
- 32 Runs
- 20 Data points/Run
- 292 Data points (i.e., $[\alpha, \beta]$ combinations)

EXAMPLE: Figure 4-11.

ANALYSIS PARAMETERS:

The ADD and RESET subcommands of SET command allow the user to declare values for certain analysis parameters, such as mach number, altitude etc. Additional analysis parameters to be declared comes from the follow up menu(s) which are displayed on the screen once above subcommands are processed.

A detailed description of the follow up menus follows.

FOLLOW UP MENU:

```
*****
*
*          ****  UDP ANALYSIS OPTION MENU  ****
*
*  0 = USE PREVIOUSLY DECLARED OPTIONS/ELSE: COMPLETELY RESET
*  1 = PRINT WING L.E. SUCTION DETAILS
*  2 = CALCULATE SYMMETRICAL MATRIX FOR ALPHA INFLUENCE
*  3 = CALCULATE ASYMMETRICAL MATRIX FOR YAW INFLUENCE
*  4 = USE EXTERNAL SOURCE FOR TWIST AND CAMBER
*  5 = INVOKE JET FLAP CAPABILITY
*  6 = INVOKE INLET-MASS-FLOW-RATIO SIMULATION CAPABILITY
*  7 = INVOKE GROUND-EFFECT CAPABILITY (MIRROR IMAGES CONFIG.)
*  8 = DECLARE INACTIVE/ACTIVE STATUS FOR PANELLED COMPONENTS
*  9 = USE ZERO THICKNESS FOR PANELLED COMPONENTS
*
*          EG:  1 2
*
*****
```

OPTION 0:

Allows user to accept previously declared options.
If none have been previously declared, the default position is that no analysis options are requested.
If zero option is not used, all previous selections are forgotten and the user simply requests analysis options desired.

OPTION 1:

Detailed printout of the various major parameters that are involved in the computation of the non-linear effect associated with the leading edge vortex calculation. L.E. vortex effects may be requested in the EDIT/PARAMETER and EDIT/PANEL subcommands.

This option also provides a detailed printout in background output of the upper and lower surface pressure coefficient for any paneled components.

-SET- (continued)

OPTION 2:

This option is almost always invoked. It is required if an α -sweep (holding β at some fixed value) has been requested in the run list schedule.

OPTION 3:

Required if $\beta \neq 0$ and/or asymmetric configuration exists. Vertical tail on the centerline does not make a configuration asymmetrical even though this is an asymmetric component in that position.

An asymmetric configuration exists if an asymmetrical flap setting is used. In this case the vertical tail on the centerline, if it has a flap (which can only be asymmetrical), causes the configuration to be asymmetrical. An asymmetric configuration exists if asymmetric components are used, for example, an oblique wing. In this case all components must be made asymmetric, i.e., no panels can be reflected across the centerline.

OPTION 4:

This option is used if the user wants to override the APAS generated twist and camber data normally computed from the input geometry file. The program will look for alternate twist and camber data from the IOPT file while executing the UDP code. A data set name for the IOPT file will be requested once the background UDP code begins to execute.

This option is normally used when an optimum twist and camber study is in progress, with data for these parameters being established from a source outside the APAS environment.

OPTION 5:

This option is requested only if a jet flap component has been constructed using the JETF command and included in the configuration. Only one jet flap component per configuration allowed.

The following example illustrates a typical data prompt/response:

```
ENTER NUMBER OF SPAN STATIONS IN JET FLAP COMPONENT
--> 4
ENTER INITIAL JET DEFLECTION ANGLE (DEG) FOR 4 JET STATIONS
(DEFAULT: 0.0 DEG)
--> 5.23 5.23 5.23 5.23
ENTER : CT (,WEIGHT1,WEIGHT2,...WEIGHT4) (DEFAULT: 1.0)
--> 0.40 1.00 1.00 1.00 1.00
```

OPTION 6:

The inlet-mass-flow-ratio simulation option is invoked if the user wants to study the effect of mass flow ratios on the aerodynamic coefficients and/or streamtube entering the inlet. The latter may be useful in conducting icing studies by using the flow field gathered via field point components and conducting particle trajectory studies. Also helpful for inlet/flow-field alignment studies.

LIMITS: Subsonic freestream mach number.

A typical prompt/response follows:

```
SPECIFY NUMBER OF INLETS (COMPONENT SYMM CODES USED)
--> 2
SPECIFY NUMBER OF CONTROL PT(S) FOR INLET #1
THE JET-WAKE WITH THE LOWEST COMPONENT NUMBER = INLET #1
--> 1
SPECIFY MFR CONTROL FACTOR - - FOR INLET #1
USING FOLLOWING FORMULA
FACTOR = (MFR*C-1)/BETA**2      WHERE:  MFR = MASS FLOW RATIO
                                   C   = ALOCAL/ACAPTURE
                                   BETA= 1-MACH**2
--> -0.39654
SPECIFY NUMBER OF PANELS ON JET-WAKE FOR INLET #1
REMEMBER; JET-WAKE COMPONENTS MUST BE THE HIGHEST NUMBERED ONES
--> 8
SPECIFY NUMBER OF CONTROL PT(S) FOR INLET #2
--> 1
SPECIFY MFR CONTROL FACTOR - - FOR INLET #2
ETC.
--> -0.39654 (Unequal values could be specified to simulate unstart)
SPECIFY NUMBER OF PANELS ON JET-WAKE FOR INLET #2
--> 8
INLET MASS FLOW CONTROL POINT LOCATION(S) FOR THE INLET(S) ARE
ENTERED BY CREATING A FIELD POINT COMPONENT. ORDER AND NUMBER
MUST AGREE WITH ABOVE INLET SPECIFICATION.
```

INLET MODEL:

INLET SIMULATION MODELING

To simulate mass flow through an inlet three components are required: (1) Inlet geometry/paneled component; (2) Jet-box geometry/paneled component; and (3) Field point component that specifies the coordinates of the control points at which the flow velocity in the inlet will be controlled. The following discussion provides an example of how to model an inlet for mass flow ratio simulation.

STEP 1: CONSTRUCT INLET GEOMETRY COMPONENT

The B-1B Inlet geometry used in this example is shown in figure 6-5. The inlet has movable cowl lips which are shown at the 40° position. Geometry is input in one of the several ways available to APAS users, i.e., CARD, DIGITIZE or TERMINAL command. This inlet is made up of five geometric components as follows. Note that they are type 3 (half surfaces).

<u>COMPN</u>	<u>NAME</u>	<u>TYPE</u>	<u>SYMM</u>
600	COWL40-INBOARD	3	2
601	LOWER S.P.-INBD	3	2
620	SPLITTER	3	2
630	LOWER S.P.-OUTBD	3	2
631	COWL40-OUTBOARD	3	2

Good flow field results in the vicinity of the inlet requires at least 3 spanwise panels for each component. Half cosine spacing using 10 chordwise has produced good results for this inlet.

The top of the inlet is the under-side of the inboard wing. Care must be taken in defining the geometric sections of the inboard wing so that the y-values of the sections line up with the leading edge y-values of components 600, 620 and 631, i.e., panel edges must be connected with panel edges. In other words, APAS lifting surface panels are created with y and z values matching the leading edge of the geometric component. Figure 6-6 shows a top view of the inboard wing & inlet geometry, verifying the proper alignment.

STEP 2: CONSTRUCT JET-BOX COMPONENT

Attached to the end of the inlet is a jet-box which simulates the jet-wake. This component is most easily constructed using the ring-wing approach as described later on. Please note the following:

- (1) The y-, z-values for the jet box are the y-, z-values associated with the leading edges of the inlet, because the APAS lifting surface paneling algorithm creates panels which are in the y and z-plane described by the leading edge coordinates of the inlet.
- (2) The leading edge x-values of the jet-box are the trailing edge x-values of the inlet.
- (3) The length of the jet box should be about two times the overall configuration length.
- (4) The jet-box components are the highest numbered paneled components of the analysis configuration.

The number of spanwise panels for each region in the jet-box must be the same as the number used on the inlet in front of it. In other words, panel edges must be followed by panel edges. Good results have been obtained using two chordwise panels on the jet-box. Figure 6-7 shows the configuration paneling as described so far.

STEP 3: CONSTRUCT FIELD POINT COMPONENT

The field point component can only be constructed using the CARD command. A sample data set is shown in Appendix A. In the present example one field point is selected in the center of each inlet at the exit plane. These field points are used by the program inlet-mass-flow ratio control points. They are selected in a region where the flow is thought to be relatively uniform. For a constant x-station specification where the flow is not uniform more than one field point should be used in the inlet.

STEP 4: SET-COMMAND

After attaching the configuration to be analyzed into the local file the SET command is entered and a run is defined. The prompts and responses made when option 6 is selected has been discussed above. The responses are straight forward except for the mass flow ratio control factor. The intention is to specify a MFR = 0.62. Using a free stream Mach number of 0.265 and a $c = 1.06$, the factor is computed to be -0.39654.

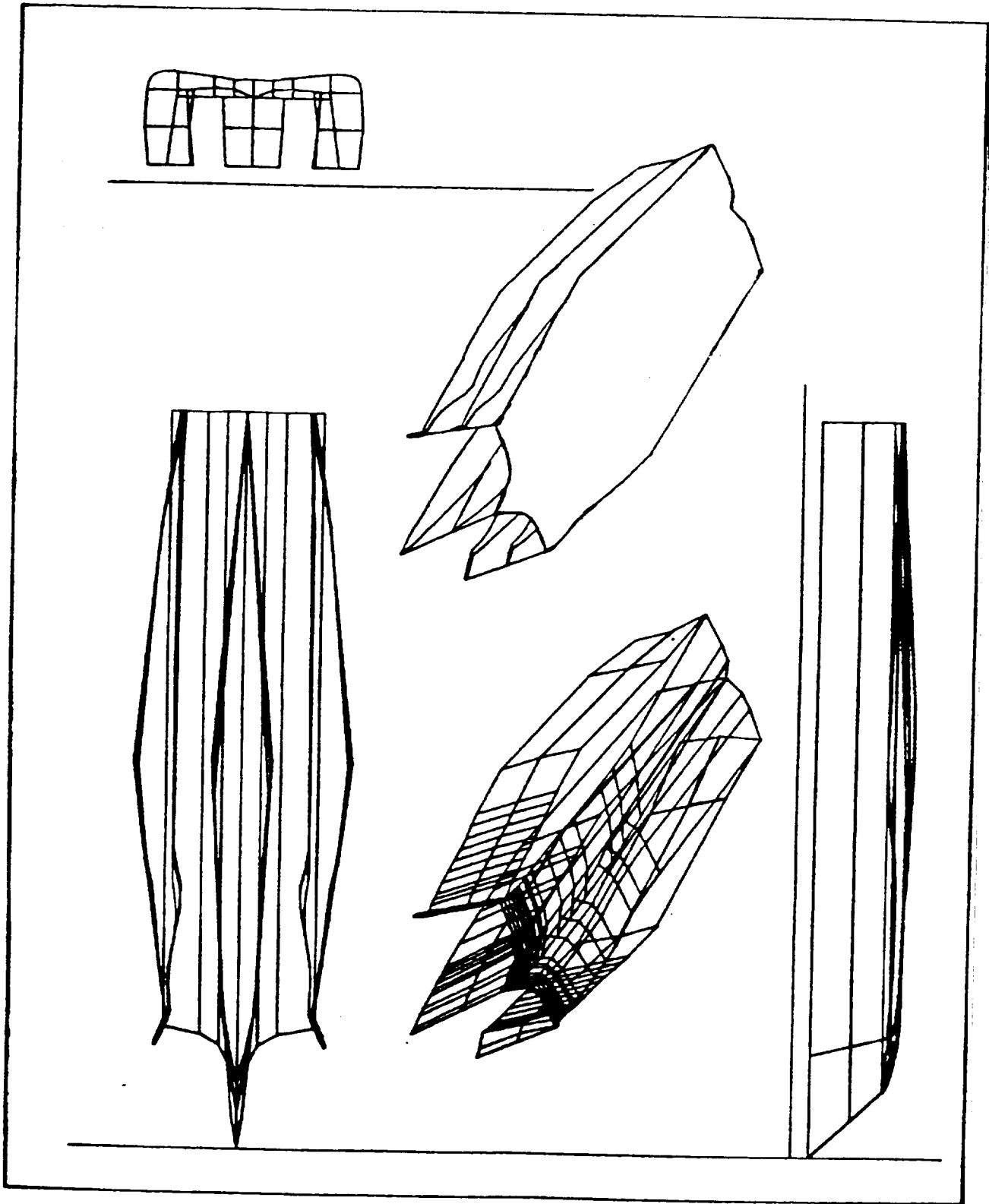


Figure 6-5. B-1B Inlet Geometry.

-SET- (continued)

INLET SIMULATION MODELING EXAMPLE

INBD WING COWL40

MENU OF KEY FUNCTIONS

INSERT - 2ND ORDER	:	I
INSERT - LINEAR	:	F
DELETE	:	D
SCALE TOP TO CURSOR	:	T
SCALE BOTTOM "	:	B
MOVE UPPER TO CURSOR	:	U
MOVE LOWER TO CURSOR	:	L
TRANSLATE COMPONENT	:	M
OVERWRITE	:	O
REPAINT	:	R
ZOOM	:	Z
WIDE	:	W
END	:	E

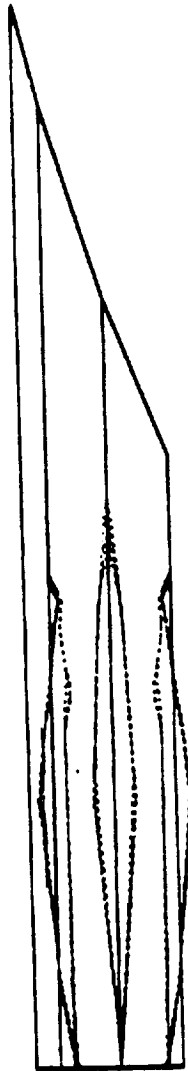


Figure 6-6. Verifying Wing and Inlet Geometry Alignment.

-SET- (continued)

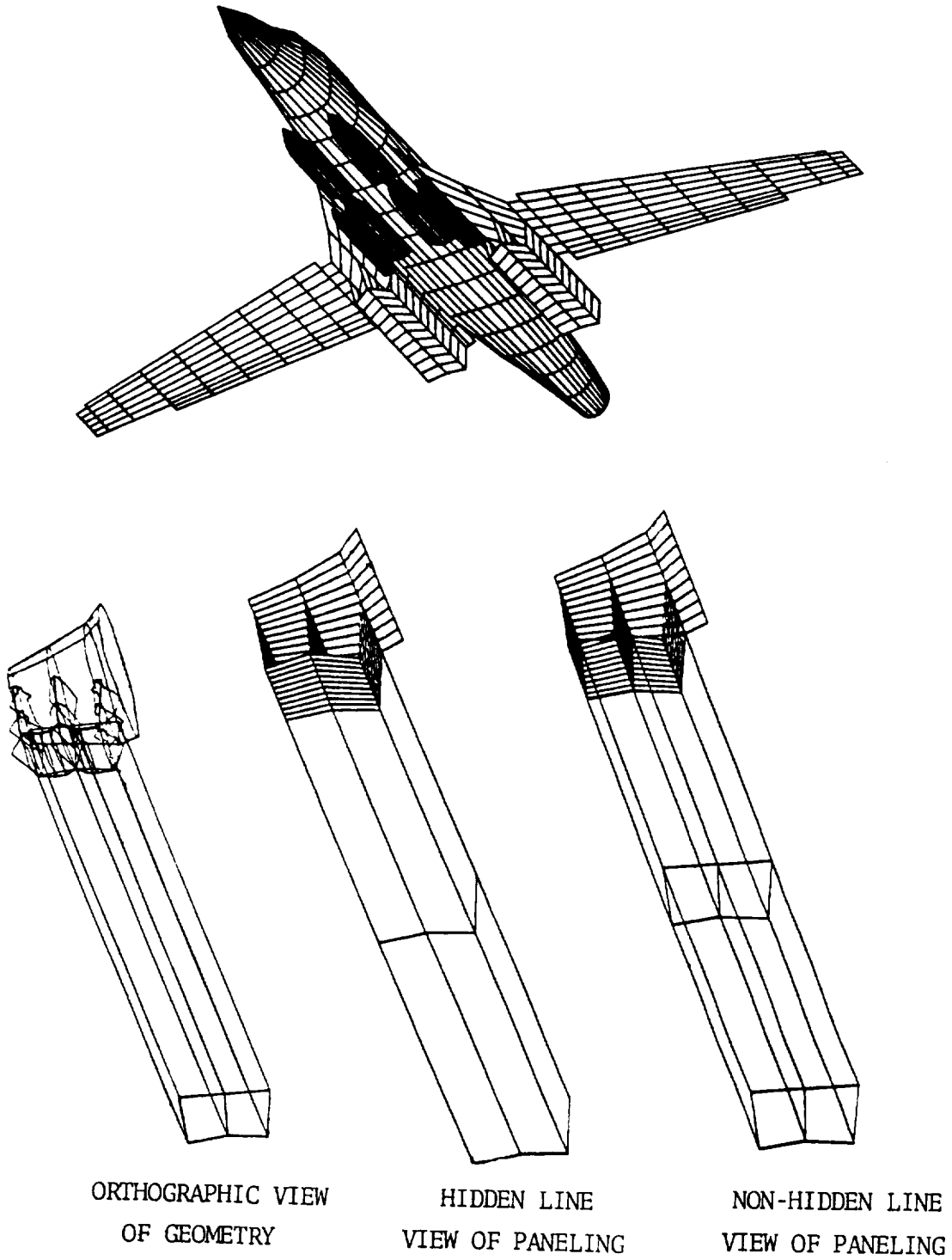


Figure 6-7. Paneled View of Inlet with Jet-Box Component.

-SET- (continued)

RING-WING CONSTRUCTION

The inlet mass flow ratio simulation requires that a jet-box be attached to the end of the inlet component. Both the inlet and jet-box components may require a ring-wing construction. The following discussion provides an example of how to construct a ring-wing starting with the TERMINAL command in APAS.

STEP 1: TERMINAL COMMAND USAGE

In figure 6-8 please note that the selection of s(in2), ar (aspect ratio) etc. are completely arbitrary. To minimize later editing it is suggested that a sweep of zero and a taper ratio of one be used. The component length and y, z values will have to be edited to form the "box" in 3-D space of your required component dimensions.

```
      **OK**
-->-->-->TERMINAL
      ENTER COMPONENT YAW,PITCH,ROLL:
-->-->--><CR>
      0.0  0.0  0.0  DEFAULTS SELECTED
      ENTER:
      1  -  FULL SURFACE
      2  -  HALF SURFACE
      3  -  FULL ELLIPSE
      +4 -  HALF ELLIPSE UP      -4  HALF ELLIPSE DOWN
      5  -  RECTANGLE
      +6 -  TRIANGLE UP        -6  TRIANGLE DOWN
      E  -  END
-->-->1
      * INPUT COMP NUMBER:
-->-->991
      * INPUT COMP NAME:
-->-->JETBOX SAMPLE
      * FULL SURFACE
      ENTER: XO(ROOT),YO(ROOT),ZO(ROOT)
-->-->--><CR>
      0.0  0.0  0.0  DEFAULTS SELECTED
      ENTER: S(IN2),AR,TAPER,SWEEP(DEG),DIH(DEG):
-->-->100 5 1.0 0. 0.
      * 1  65 A OXX
      * 2  64 A OXX
      * 3  SUPERCRITICAL
      * 4  HEX AIRFOIL
      * 5  BI-CONVEX
      * SELECT AIRFOIL TYPE:
-->-->4
      * ENTER: (T/C)1, (T/C)2 ..., (T/C)N, N < = 10
      (DEFAULT VALUES: 0.05,0.05)
-->-->0.0 0.0
      **OK**
-->-->CATA
```

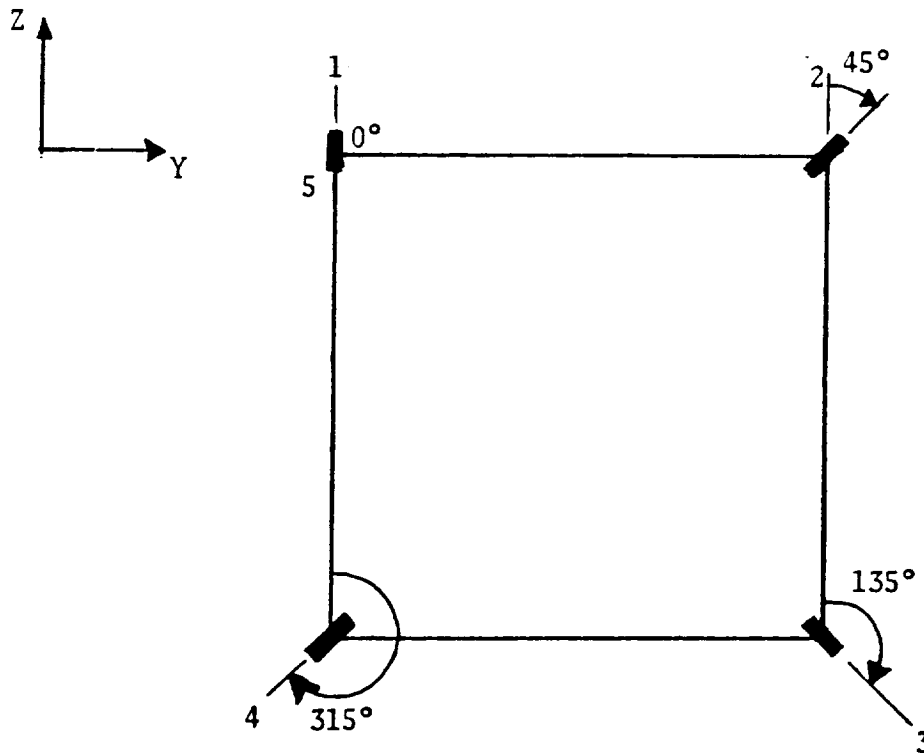
Figure 6-8. Start of Ring-Wing Construction Using TERMINAL Command.

STEP 2: EDIT/VIEW COMMAND

Figure 6-9 shows an edit-view of component. Delete as many sections as you desire, leaving in this case four spanwise regions (5 sections) as shown in figure 6-10. The unevenness of the region size is unimportant since this will be controlled by editing later on in the process.

STEP 3: EDIT/B COMMAND

The B-subcommand of the EDIT command can be used to change the dihedral of an airfoil section. Figure 6-11 shows an application of the command. The goal is to wrap the wing around as shown in the rear view of the component below.



Rear View of Component.

-SET- (continued)

STEP 4: EDIT/X,Y,Z COMMAND

The component coordinates can now be moved in space. This example will form a box which starts with the first section at $y = z = 0$. (unchanged) The second section will remain unchanged at $y = 2.2361$, $z = 0.0$. However, the third section requires that y be changed to 2.2361 as shown in figure 6-12. Z has already been changed to -2.2 . Section four requires that $y = 0$ and $z = -2.2$. Finally, section five requires that $y = 0$. One can also lengthen the component at this point (x -changes) if desired.

STEP 5: EDIT/PANEL COMMAND

The jet-box is paneled using two chordwise and three spanwise panels. The paneling is accomplished in the usual manner.

STEP 6: DR COMMAND

This command allows user to have any view of a paneled component(s). An end-view (0,0,0) will allow verification of the box shape.

RING-WING CONSTRUCTION EXAMPLE

JETBOX SAMPLE

EDIT**

MENU OF KEY FUNCTIONS
INSERT - 2ND ORDER : I
INSERT - LINEAR : F
DELETE : D
SCALE TOP TO CURSOR : T
" BOTTOM TO CURSOR : B
MOVE UPPER TO CURSOR : U
MOVE LOWER TO CURSOR : L
TRANSLATE COMPONENT : M
OVERWRITE : O
REPAINT : R
ZOOM - ENLARGE IMAGE : Z
WIDE - SHRINK IMAGE : W
END : E

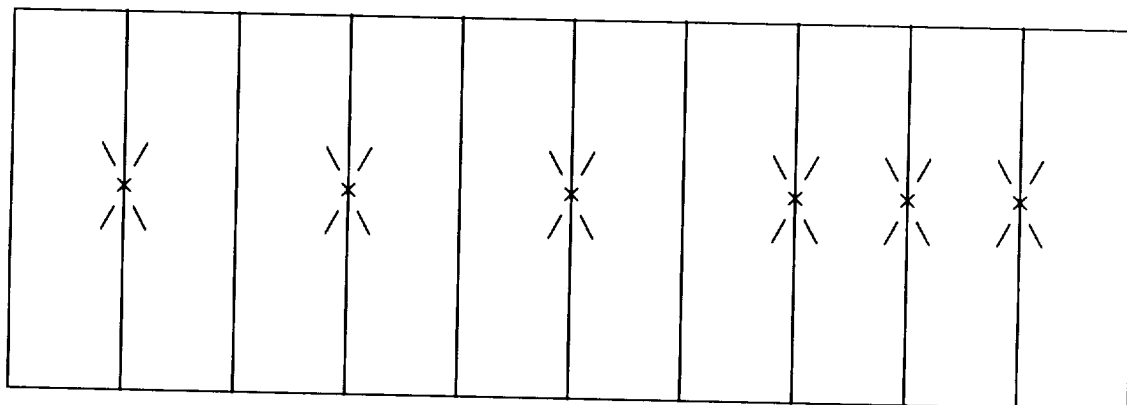


Figure 6-9. EDIT/VIEW of Ring-Wing Component with Section Deletion.

-SET- (continued)

RING-WING CONSTRUCTION EXAMPLE

JETBOX SAMPLE

MENU OF KEY FUNCTIONS

INSERT - 2ND ORDER : I
INSERT - LINEAR : F
DELETE : D
SCALE TOP TO CURSOR : T
" BOTTOM TO CURSOR : B
MOVE UPPER TO CURSOR : U
MOVE LOWER TO CURSOR : L
TRANSLATE COMPONENT : M
OVERWRITE : O
REPAINT : R
ZOOM - ENLARGE IMAGE : Z
WIDE - SHRINK IMAGE : W
END : E

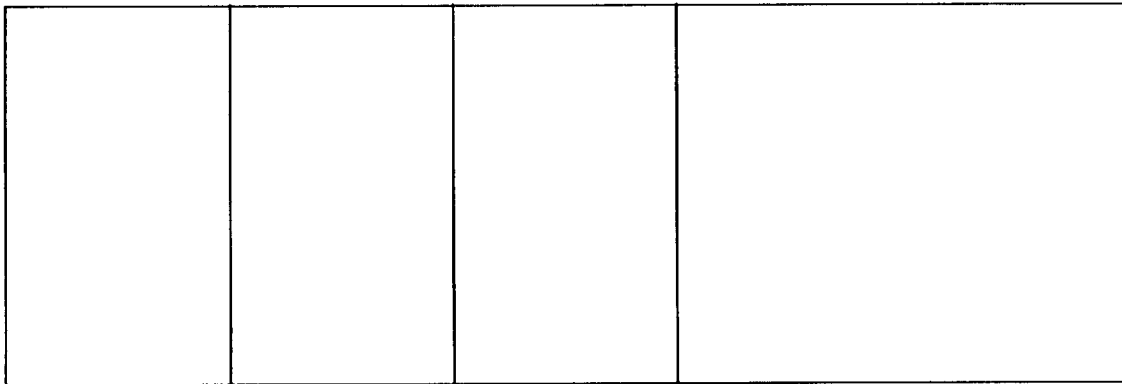


Figure 6-10. EDIT/VIEW of Ring-Wing Component with Reduced Sections.

-SET- (continued)

```

--> 2,B=45
  ** 2 1 -0.00000 2.23606 0.00000
  ** 2 2 1.34163 2.23606 0.00000
  ** 2 3 3.13048 2.23606 0.00000
  ** 2 4 4.47212 2.23606 0.00000
  ** 2 5 4.47212 2.23606 0.00000
  ** 2 6 3.13048 2.23606 0.00000
  ** 2 7 1.34163 2.23606 0.00000
  ** 2 8 -0.00000 2.23606 0.00000
  EDIT**
--> 3,3=135
  EDIT**

--> 4,3=315
  EDIT**
--> S
  SAVED IN PERM FILE
  EDIT**

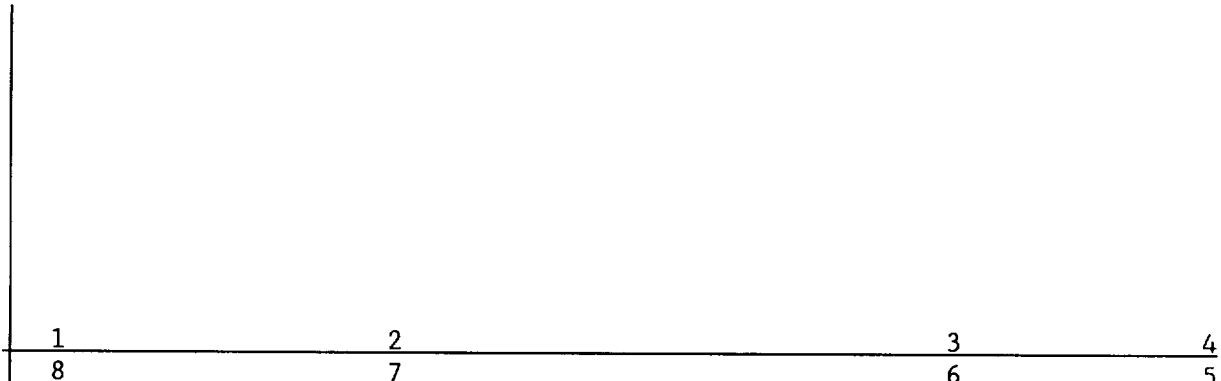
```

Figure 6-11. Ring-Wing Component Modification Using EDIT/B.

```

  EDIT**
--> Y=2.2361 SECTION: 3 991.00 JETBOX SAMPLE
  EDIT**

```



1	-0.0000	4.4721	-2.2000
2	1.3416	4.4721	-2.2000
3	3.1305	4.4721	-2.2000
4	4.4721	4.4721	-2.2000
5	4.4721	4.4721	-2.2000
6	3.1305	4.4721	-2.2000
7	1.3416	4.4721	-2.2000
8	-0.0000	4.4721	-2.2000

Figure 6-12. Ring-Wing Component Modification Using EDIT/X,Y,Z.

OPTION 7:

If ground effects are important, this option should be requested. Normally a vehicle is said to be in ground effect if distance from ground is less than two wing spans.

The user does not have to alter the analysis configuration in any way to use this option. APAS simply mirror-images all panels in the configuration, through a matrix manipulation, to the other side of the ground plane. In this way the ground plane is exactly represented.

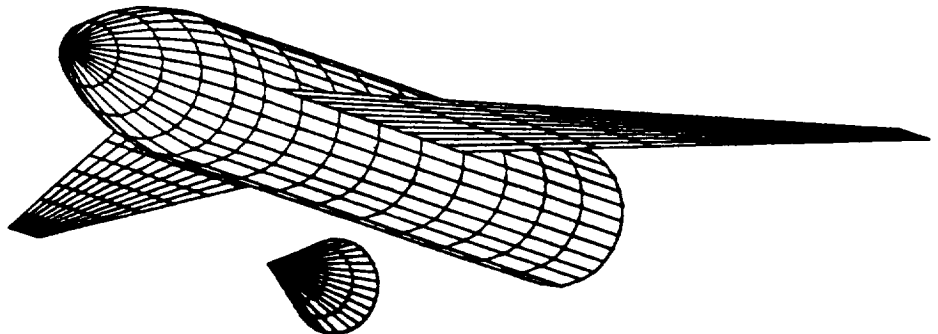
OPTION 8:

Useful for store separation and ground effect studies. Allows the user to obtain aerodynamic characteristics of one or more components while in the presence of the complete configuration. The boundary conditions specified in the run schedule are for the active components in the configuration only. The inactive components have boundary conditions of the basic solution (typically, $\alpha=\beta=\gamma=0.0$). The initial incidence may be changed by using the EDIT/PARAMETER command.

EXAMPLE 1: MISSILE IN PRESENCE OF A WING/BODY COMBINATION

DISPLAY ANGLES	YAW ,	PITCH ,	ROLL	PANELS	1 THRU 332
	15.00	5.00	5.00		

Consider a missile in the presence of a wing/body combination. It is desired to obtain the missile aero characteristics while in the vicinity of the rest of of the configuration.



-SET- (continued)

Step 1: RIGGING THE INITIAL INCIDENCE OF THE CONFIGURATION

The initial incidence boundary condition for paneled components is declared in the EDIT/PARAMETER command by setting the ALC (-ALPHA) parameter. The initial incidence of a slender body is automatically determined within APAS from the value specified for its shell.

Step 2: DECLARING ACTIVE/INACTIVE SETTING FOR THE PANELED COMPONENTS

At this point it is assumed that the user has attached a configuration to the local file, entered the SET command, defined a run number for the configuration, and has requested option 8 from the UDP analysis options menu. The following prompt/response polling is then entertained. After each paneled component name and present initial incidence angle are displayed, the user is prompted to declare the active/inactive setting.

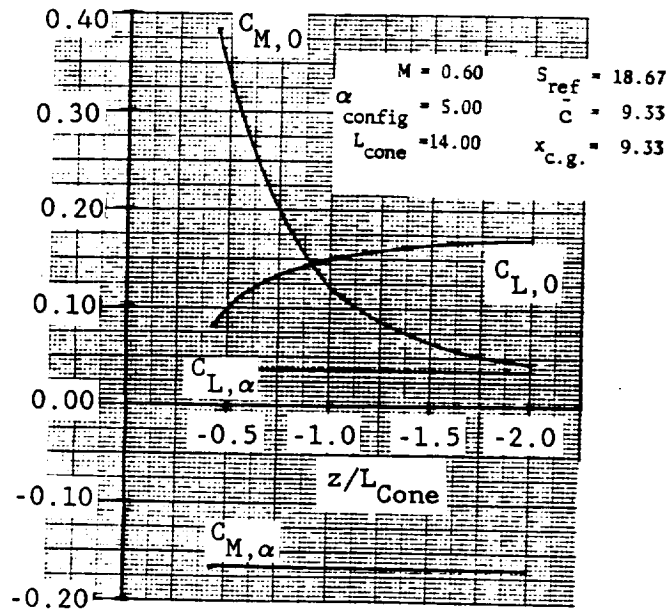
```

      DECLARE ACTIVE/INACTIVE STATUS FOR FOLLOWING COMPONENTS (1=ACTIVE,
      0=INACTIVE) INITIAL INCIDENCE OF CONFIGURATION COMPONENTS IS
      DECLARED IN EDIT/PARAMETER COMMAND
      NCOMP= 3
      MISSILE SHELL      PRESENT VALUE OF INCIDENCE  5.00
      ENTER 1 OR 0
--> 1
      B INTF SHELL      PRESENT VALUE OF INCIDENCE  5.00
      ENTER 1 OR 0
--> 0
      NASA TN D-8361 W  PRESENT VALUE OF INCIDENCE  5.00
      ENTER 1 OR 0
--> 0
      DO YOU WANT TO RESET REFERENCE QUANTITIES TO
      VALUES APPROPRIATE FOR INACTIVE COMPONENT(S) ARRANGEMENT. Y OR N
--> Y
      CONFIGURATION: 1
      SREF: 1290.00      CBAR: 12.6000      SPAN: 45.0000
      ENTER NEW VALUES OR CARRIAGE RETURN:
--> 18.67 9.333 4.88
      XCG : 12.6000      YCG : .0          ZDG : .0
      ENTER NEW VALUES OR CARRIAGE RETURN:
--> 9.3333 0 -8.0
```

The reference quantities may also be changed at this time in order to reflect the values appropriate for the determination of the aerodynamic characteristics of the active components. In this case the missile base area, centroid location, base diameter, and z-location relative to the wing/body combination are input.

The following graph shows that the missile's C_{M0} and C_{L0} are substantially altered, while the $C_{M\alpha}$ and $C_{L\alpha}$ are not affected by being in close proximity to the wing/body combination of a low aspect ratio, highly swept wing and a conical shaped missile apparently does not produce as strong an interaction as will be seen in the next example.

-SET- (continued)

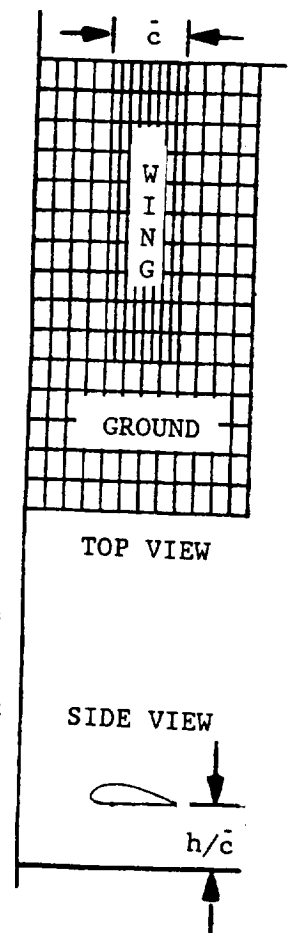


Example 2: NASA TN D-926 WING IN GROUND EFFECT

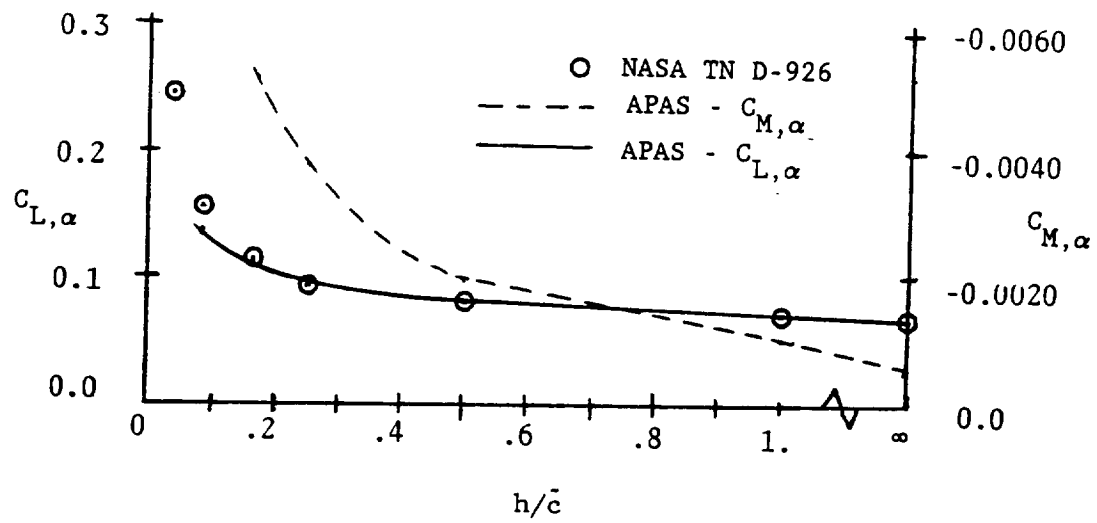
A ground-effect machine as a large overwater transport has sparked considerable interest from time to time. NASA conducted a wind-tunnel investigation to determine the effect of ground proximity on the aerodynamic characteristics of thick (22%-for cargo space considerations), highly cambered, unswept wings with various aspect ratios. The following example uses the aspect ratio of four model of the NASA geometry in APAS. In this APAS model, shown alongside, the ground is paneled. An alternate method in APAS allows the user to select an analysis option to reflect the configuration (wing in this case) about some imaginary z-located ground plane. However, for the purposes of demonstrating the use of option 8, the ground paneled model is presented here.

As in the previous example, the initial incidence of the configuration is established (zero in present example). Then the active/inactive setting for the paneled components is declared (wing = active, ground = inactive).

The following graph compares APAS results with NASA TN D-926 data. The $C_{L,\alpha}$ result compares favorably. No data were available on $C_{M,\alpha}$. Other data comparisons show: 1) good agreement on drag; (2) APAS computes increasing values of lift coefficient at $\alpha=0$ as the ground is approached, whereas NASA data has the lift coefficient at an angle of attack of 0 remaining nearly constant as the ground is approached; and (3) C_M vs h/c has the right sign but is about 50% to large.



-SET- (continued)



OPTION 9:

The zero thickness option is useful for comparing APAS results with flat plate wind tunnel models. Another application would be for studying the differential effects of thickness on the aerodynamic coefficients.

-SET- (continued)

FOLLOW UP MENU:

```
*****
*
*          ****  HABP ANALYSIS OPTION MENU  ****
*
*  0 - ACCEPT DEFAULT OPTIONS/ELSE: COMPLETELY RESET
*  1 - DO NOT INCLUDE COMPONENT SHIELDING EFFECTS
*      DEFAULT:  INCLUDE COMPONENT SHIELDING
*  2 - SET MODEL SCALE
*      DEFAULT:  MODEL SCALE=1.0 IS FOR INPUT GEOMETRY
*  3 - DO NOT INCLUDE SKIN FRICTION EFFECTS IN ANALYSIS
*      DEFAULT:  INCLUDE SKIN FRICTION EFFECTS
*  4 - DO NOT ADD HEMISPHERICAL NOSE TO BODY PANELS
*      DEFAULT:  ADD HEMISPHERICAL NOSE CAP BETWEEN 1ST AND
*                2ND INPUT GEOMETRY SECTIONS IF INPUT BODY
*                NOSE HALF CONE ANGLE IS GREATER THAN 30 DEG
*
*      EG:  1 4
*****
```

OPTION 0:

Allows user to accept previously declared options.
If none have been previously declared, the default positions are used.
If zero option is not used, all previous selections are forgotten and the user simply requests analysis options desired.

OPTION 1:

When the shielding option is requested a data set is created which identifies all visible panels. Impact forces will not be included in the aerodynamic coefficients for invisible panels. Skin friction effects will be included for the invisible panels.

When the shielding option is used, the execution times increase by a factor of three. Normally this option is used as a refinement calculation. Experience has shown that including the effects of shielding tends to improve L/D , C_D and C_M predictions relative to data.

If shielding is requested the following menu appears.

-SET- (continued)

```
*****
*
*          **** SPECIFY SHIELDING OPTION ****
*
*  ENTER: 1 - SHIELDING EFFECTS      ARE NOT REQUESTED
*
*          2 - SHIELDING EFFECTS      ARE      REQUESTED
*
*          3 - SHIELDING EFFECTS DATA ALREADY EXIST - USE.
*          USER BEWARE:  OPTION 3 REQUIRES -
*
*          (A) THAT A PREVIOUS RUN USING OPTION 2 WAS EXEC
*          (B) THAT (A) WAS THE ONLY RUN OR THE LAST RUN
*          (C) THAT THE DATA CREATED IN (A) WAS SAVED, I.E.,
*          FOR IBM USERS THE JOB WAS SUBMITTED, USING-
*          ANAL @ @ 999 NEW P(3) HYPDSP(KEEP)
*  AND RERUN USING ANAL @ @ 999 NEW P(3) HYP(OLD) HYPDSP(KEEP)
*****
```

Entry 1 and 2 are self explanatory. Entry 3 can be a time saver when multiple mach, altitude conditions are to be run. However, the (α, β) combinations must be the same as well as any flap deflections. For runs re-using the shielding data, completion times are shorter than the case when no shielding is requested.

OPTION 2:

The model scale option allows the user to compute HABP aerodynamics on one geometry that can represent either a full-scale vehicle or a wind tunnel model. Model scale=1.0 is for input geometry.

OPTION 3:

With this option the user can turn skin friction effects on or off and thus study the differential effects between impact forces and skin friction. The original Mark III code requires two geometry models, one for impact forces and the other for skin friction. The APAS version of the Mark III code has been upgraded so that only one geometry model is used. Basically, skin friction effects are not calculated in the leading edge regions of the surface components in the model (Reynolds number typically approaches zero).

The following menu appears when this option is requested.

-SET- (concluded)

```
*****
*
*          **** SPECIFY SKIN FRICTION OPTION ****          *
*
*   ENTER: 0 - TURBULENT                                     *
*
*           1 - LAMINAR                                       *
*
*           2 - LAMINAR TO TURBULENT TRANSITION              *
*
*****
```

Entry 0, requests turbulent skin friction calculation for entire model while entry 1 would make the choice laminar. Entry 2 lets the code decide, based on transition Reynolds number, which portions of the vehicle are in laminar flow and which in turbulent.

OPTION 4:

Since all the drag, due to impact forces, comes from the forward facing (visible only used if shielding is on) portions of the model surface - it is important to accurately model these regions. Especially the leading edge and nose regions where impact angles change most rapidly. Because of this consideration a hemispherical nose cap option is provided for insertion between the first and second section of the most forward facing body component.

-SET-/ADD

SUBCOMMAND: ADD

```
ADD[n] [,RUN(r)] [, [ALPHA(a1,...,an)] [BETA(b1,...,bn)]]  
[,MACH(m)] [,ICOND1(ic1,...,ICONDn(icn)] [,CONFIG(c)]  
[, [AIR][HELIUM][CFFOUR]] [, [NOPRINT][PRINT]]  
[, [SHKOFF][SHKEXP]] [, [HYPOFF] [HYPER]] [, [LINEAR] [FIXED]]
```

OPERANDS:

- | | |
|------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| n | - SET number to concatenate onto add list ($n \leq 12$).
(See SET/SET subcommand for SET number origin) |
| RUN(r) | - Run number (r). Any value between 1 and 9999 can be used in ascending order. |
| [A]LPHA(a ₁ -a _n) | - Angle-of-attack list. Either ALPHA or BETA list should be specified or a run with only one data point will result (which is not permitted). |
| [B]ETA(b ₁ - b _n) | - Angle-of-sideslip list. |
| [M]ACH(m) | - Mach number. |
| ICOND _i (ic _i) | - Initial condition (ic) for analysis calculations.
See table 9 for list of keywords. |
| [C]ONFIG(c) | - Configuration to use for analysis.
Default is the highest or most recent. |
| AIR | - Atmosphere for hypersonic analysis. |
| HELIUM | Default is air. |
| CFFOUR | CF ₄ (carbon tetrafluoride) ¹¹ . |
| NOPRINT | - Diagnostic print for hypersonic runs. Increases |
| PRINT | output by a factor of ten.
Default is NOPRINT. |

-SET-/ADD (continued)

- | | |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SHKOFF
SHEXP | - Shock expansion indicator for hypersonic flap deflection calculations.
Default is SHKOFF. |
| HYPOFF
HYPER | - Hypersonic analysis indicator. Mach numbers less than 4.0 default to the subsonic-supersonic analysis unless the HYPER keyword is invoked.
Default is HYPOFF. |
| LINEAR
FIXED | - Subsonic-supersonic source(thickness) solution indicator.
Default is LINEAR.
Experience has shown best results are obtained using FIXED for subsonic flows and LINEAR for supersonic conditions. Flap(s) must be at constant % chord when using the LINEAR option to avoid possible singularities, emanating from sonic leading edges, passing through control points on adjacent panels. |

ABBREVIATION: None.

FUNCTION: Enter a new run into the input file for background analysis. When used with a setlist, the amount of input required and possible errors are considerably reduced. Required information will be requested by the system if not provided in the ADD statement.

EXAMPLE: Figure 4-12.

Table 9. Analysis Initial Conditions.

ALPHA	- [A] Initial angle of attack, degrees.
BETA	- [B] Initial sideslip angle, degrees.
P	- Roll rate, radians/sec.
Q	- Pitch rate, radians/sec.
R	- Yaw rate, radians/sec.
D1 ,...,D6	- Flap deflection angles, degrees.
ALTITUDE	- [ALT] Altitude, meters or feet.
KS	- Equivalent sand grain height, meters, inches or cm for viscous drag calculations (See Table 11). Required for subsonic-supersonic analysis only.
PRESSURE	- [PR] Stagnation pressure, Nt/m^2 or Lb/ft^2 . Not required when altitude is specified.
TEMPERATURE	- [T] Stagnation temperature, Kelvin or Rankine. Not required when altitude is specified.

Initial conditions are the parametric values which define the configuration attitude and atmospheric conditions at which a given run is to be analyzed. A string of these conditions are input with the ADD or RESET subcommands which will then define the attributes utilized at the time each run in the analysis file is executed. The SET subcommand is a convenient way to maintain a group of preset lists of initial condition strings which are used repeatedly.

Mach number, altitude or temperature and pressure, and sand grain height (for non-hypersonic runs) initial conditions will be requested by the system if the user fails to input them when adding a run to the analysis file.

Angle of attack or sideslip may be specified to have from 2 to 20 values in a given run. They are the independent variables in the same sense as a wind tunnel test.

-SET-/DELETE

SUBCOMMAND: DELETE

DELETE,*1[,*2,...*n]
*=R or C or SET

OPERANDS:

- R - Run number(s) to delete from input file.
Delete one run at a time starting with highest number.
Deleting runs other than highest numbered one ruins the input file.
- C - Configuration number(s) to delete from input file.
Delete one configuration at a time, starting with the highest numbered one.
- SET - Set list number(s) to delete from user file.
Can be deleted in any order.

ABBREVIATION: DEL

FUNCTION: Provides input and user file data management.

EXAMPLES:
DEL,R32
DEL,C9
DEL,SET2

-SET-/END

SUBCOMMAND: END



END

OPERANDS: None.

ABBREVIATION: E

FUNCTION: Ends run list definition activity of SET and initiates
the aerodynamic model validation and/or hypersonic
algorithm assignment phase.

EXAMPLE: Figures 4-14 through 4-24.

-SET-/LIST

SUBCOMMAND: LIST

LIST[,CONFIG(N)]
[,R(N)]

OPERANDS:

- [C]ONFIG - List specific configuration number.
Default is "ALL" if a number is not specified.
- R - List specific run number.
Default is "ALL" if a number is not specified.

ABBREVIATION: L

FUNCTION: Displays configuration of run data. Among other data, a list of the run data indicates run status, i.e., a keyword of either ANALYZED or SET appears in first line of data. If SET appears, it means the run is "set" ,i.e., waiting to be analyzed. If ANALYZED appears, it means the run has been "analyzed" and the user can view the analysis results using the PLOT command.

EXAMPLES: Figure 4-13; L,R5

-SET-/PL

SUBCOMMAND: PL



PL

OPERANDS: None.

ABBREVIATION: None.

FUNCTION: Allow the numerical list of 50 plot variables for a specified run and angle of attack (or sideslip). User can edit this plot information to input wind tunnel or computational data for comparison in the PLOT command.

EXAMPLES: 238

```

**SET**                                (starting in SET mode)
---> p1
ENTER RUN NUMBER
---> 1
SELECT ALPHA    0.0    5.0    10.0
---> 5.0
PLOT FILE OUTPUT FROM BACKGROUND ANALYSIS UDP/HABP

```

(screen display split for clarity)

(columns)

(1	2	3	4	5)
TTOTAL	PTOTAL	PFS	Q	RN/L
2353.5	49588.0	93.7	1640.2	2254071.0
CD	CDP	CDM	CDZERO	CD100
0.00456	0.00015	0.00	0.0000	0.000
CYB-SIDE	CNB-YAW	CRB-ROLL	ALPHA	BETA
0.00000	0.00000	0.0000	5.000	0.000
CYLIN	CNLIN	CRLIN	CLALIN	CMALIN
0.00000	0.00000	0.00000	0.00000	0.00000
CL-BASIC	CM-BASIC	CY-BASIC	LEVTXR	LEVTXL

(columns)

(6	7	8	9	10)
MACH	CN	CA	CL	CM
5.00	0.06066	0.0015	0.05036	0.00843
CY-SIDE	CN-YAW	CR-ROLL	CLA	CMA
0.0000	0.00000	0.00000	0.01164	0.00197
DCMDCL	LOD	ANALYSIS	CLLIN	CMLIN
.10928	11.048	2.0	0.0360	0.0054
CYBLIN	CNBLIN	CRBLIN	CDL	CDBASE
0.0000	0.0000	0.0000	0.0023	0.0000
TIPVTXR	TIPVTXL	CDZERO	XAC	NPANELS
0.0000	0.0000	0.000	*****	450

```

SELECT DATA LOCATION NUMBER (1 TO 50) FOR MODIFICATION OR ENTER ZERO
---> 0.0
ENTER    1    TO EDIT /VIEW CP DATA
         0    TO END
---> 0
** SET **

```

Example PL command Output Summary for Run 1 and Angle of Attack of 5 degrees

-SET-/PR

SUBCOMMAND: PR



PR

OPERANDS: None.

ABBREVIATION: None.

FUNCTION: Allow the numerical display of run input variables for a specified configuration and run. User can edit configuration or run input information.

EXAMPLES: 240,241,242

```

**SET**                                     (starting in SET mode)
--> PR>
      (display is line wrap-around for clarity)

      ENTER CONFIGURATION NUMBER ZERO TO SKIP
--> 1
      INPUT FOR BACKGROUND ANALYSIS (CONFIGURATION 1) FROM PLOT FILE

      NRUN, NOCPS, NOCOF TITLE = 14 0 0 PANELED BODY USING SHUTTLE
--> geom1.data
      ME, NADD, IDD(1-31) = 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
      NCONFIG, ISUCTG, ITYP(10) = 9 1 1 1 1 1 1 1 1 1 1 1
      ISS, IAS, NINLET, NCPTS(5), FACTOR(5) NTJ(5) = 2 0 0 0 0 0
0 0 0.00 0.00 0.00 0.00 0.00 0 0 0 0 0
CONFIG =      1      210.00      0.00      0.00      0.00      0.00
0.00      0.00      0.00      0.00
      0.0      0.00      0.00      0.00      0.00      0.00
0.00      0.00      0.00      0.00
      0.00 387360.0 474.7      936.7      1076.7      0.0
-25.0
NCOMP, IACTIV = 1 0
      ENTER RUN NUMBER, ZERO TO SKIP
--> 1
      INPUT FOR BACKGROUND ANALYSIS (RUN # 1) FROM PLOT FILE
      IRUN      NAB      NPRTS      NRS      NVAR
      1          3          5          25          1
      MACH      PSTATIC      TSTATIC      ALTITUDE      ALPHA
      -5.0      93.72      392.25      70000.00      0.00
      BETA      P          Q          R          D1
      0.00      0.00      0.00      0.00      0.000
      D2      D3      D4      D5      D6
      0.00      0.00      0.00      0.00      0.000
      ALPHA OF BETA ANGLES SPECIFIED FOR ANALYSIS SWEEP - UP TO 20 VALUES MAY
      BE ENTERED
      0.000      5.00      10.00      15.00      20.00      0.000      0.000
0.00      0.00      0.00
      0.000      0.00      0.00      0.00      0.00      0.00      0.00
0.00      0.00      0.00
      NPRESS1      NPRESS2      NPRESS3      NPRESS4      NPRESS5
      1          2          3          4          3
      PROT      ICONF      IGAS      CT      ISOL
      14          9      100      -1.0      0
      SELECT DATA LOCATION NUMBER (1-50) FOR MODIFICATION OR ENTER ZERO
--> 0
** SET **

```

Example PR command Configuration and Run Input Option Summary

TABLE 10

EDIT SUB-COMMAND PR VARIABLE NAME DEFINITION
Configuration Information

VARIABLE	USE
NRUN	run number
TITLE	LOCAL file title
ME	units indicator (ME = 2 is inches)
NCONFG	number of configurations defined
ISUCTG	leading edge suction indicator
ISS	Symmetric matrix calculation indicator
IAS	Asymmetric matrix calculation indicator 1 for asymmetric matrix requested (SET menu option 3)
NINLET	number of inlets (SET menu option 6)
NCPTS(5)	number of control points of each inlet
FACTOR(5)	mass flow ratio for each inlet
CONFIG(27)	number of components in configuration component number(s) (limit 20 components) reference area reference span mean aerodynamic chord X center of gravity Y center of gravity Z center of gravity
NCOMP	UDP only - component number to be removed from force summation (declared inactive in SET menu option 8)
IACTIV	UDP only - flag that components are to be removed from force summation

TABLE 10 (continued)

EDIT SUB-COMMAND PR VARIABLE NAME DEFINITION

(Run information)

VARIABLE	USE
IRUN	run number negative if runs are set to be analyzed positive if runs have been analyzed
NAB	number of angle of attacks or betas
NVAR	flag for angle of attack or beta as independent variable 1 for angle of attack 2 for beta
MACH	Mach number negative for HABP analysis positive for UDP analysis
D1 to D6	flap deflection angles
ALPHA (or BETA)	angle of attack or beta values (limited to 20 values)
PROT	HABP only - HABP shielding flag and skin friction transition option request (two digit definition) right digit is transition option flag 0 all turbulent 1 all laminar 2 transition based on Reynolds number referenced to x 3 Transition based on Reynolds number referenced to boundary layer parameter theta left digit is HABP shielding option flag 1 shielding effects are not requested 2 shielding effects are requested 3 shielding effects previously calculated (and saved) and reuse for this run
ICONF	configuration number
IGAS	HABP only- HABP gas flag AIR, HELIUM or CH4
ISOL	UDP only - UDP thickness source indicator 0 for linear (varying spanwise) source 10 for fixed (constant spanwise) source

-SET-/REFERENCE

SUBCOMMAND: REFERENCE

REFERENCE[c]

OPERANDS:

c - Configuration number.
Default is "ALL" if a number is not specified.

ABBREVIATION: REF

FUNCTION: Used to verify or respecify reference data by configuration.
Reference data changed for runs already analyzed will
result in incorrect output data, unless they are re-analyzed.

PROMPT/RESPONSE:

```
→→→ REFc
    CONFIGURATION: c
    SREF:sref CBAR:cbar SPAN:span
    ENTER NEW VALUES OR CARRIAGE RETURN:
→→→ srefnew,cbarnew,spannew
    XCG: xcg YCG: ycg ZCG: zcg
    ENTER NEW VALUES OR CARRIAGE RETURN:
→→→ xcgnew,ycgnew,zcgnew
    ***WARNING *** DATA FROM RUNS USING THESE UPDATED ***
    *** REFERENCE QUANTITIES MAY NOW BE IN ERROR ***
```

-SET-/RESET

SUBCOMMAND: RESET

```
RESET[n] [,RUN(r)] [,ALPHA(a1,...,an)] [BETA(b1,...,bn)]  
[,MACH(m)] [,ICOND1(ic1,),...,ICONDn(icn)] [,CONFIG(c)]  
[, [AIR] [HELIUM] [CFFOUR]] [, [NOPRINT] [PRINT]]  
[, [SHKOFF] [SHKEXP]] [, [HYPOFF] [HYPER]] [, [LINEAR] [FIXED]]
```

OPERANDS:

- RUN(r) - Run number (r). Any value between 1 and 9999 can be used in ascending order.
- [A]LPHA(a₁-a_n) - Angle-of-attack list. Either ALPHA or BETA list should be specified or a run with only one data point (α, β) combination will result (which is illegal). Number of values entered must be less than or equal to the original number.
- [B]ETA(b₁ - b_n) - Angle-of-sideslip list.
- [M]ACH(m) - Mach number.
- ICOND_i(ic_i) - Initial condition (ic) for analysis calculations.
See Table 9 for list of analysis initial conditions.
- [C]ONFIG(c) - Configuration to use for analysis.
Default is the highest or most recent.
- AIR - Atmosphere for hypersonic analysis.
HELIUM - Default is air.
CFFOUR - CF₄ (carbon tetrafluoride).

-SET-/RESET (concluded)

- | | |
|------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NOPRINT
PRINT | - Diagnostic print for hypersonic runs. Increases output by a factor of ten.
Default is NOPRINT. |
| SHKOFF
SHKEXP | - Shock expansion indicator for hypersonic flap deflection calculations.
Default is SHKOFF. |
| HYPOFF
HYPER | - Hypersonic analysis indicator. Mach numbers less than 4.0 default to the subsonic-supersonic analysis unless the HYPER keyword is invoked.
Default is HYPOFF.
If HYPER keyword is invoked, it must be the last entry on the RESET command string. |
| LINEAR
FIXED | - Subsonic-supersonic source (thickness) solution indicator.
Default is LINEAR.
Experience has shown best results are obtained using FIXED for subsonic flows and LINEAR for supersonic conditions. Flap(s) must be at constant % chord when using the LINEAR option to avoid possible singularities (emanating from sonic leading edges) passing through control points on adjacent panels. |

ABBREVIATION: None.

FUNCTION: Modification of an existing run or changing a run from ANALYZED to SET (analysis status).
If modifying, only updates need be entered.

EXAMPLE: Figure 4-13.

-SET-/SET

SUBCOMMAND: SET

```
SET[n] [,ALPHA(a1,...,an)] [BETA(b1,...,bn)]  
[,MACH(m)] [,ICOND1(ic1,),...,ICONDn(icn)] [,CONFIG(c)]  
[,AIR] [HELIUM] [CFFOUR] [,NOPRINT] [PRINT]  
[,SHKOFF] [SHKEXP] [,HYPOFF] [HYPER] [,LINEAR] [FIXED]
```

OPERANDS:

- n - SET number of this variable list. (n≤12)
- [A]LPHA(a₁-a_n) - Angle-of-attack list. Either ALPHA or BETA list should be specified or a run with only one data point (α,β) combination will result(which is illegal). Number of values entered must be less than or equal to the original number.
- [B]ETA(b₁- b_n) - Angle-of-sideslip list.
- [M]ACH(m) - Mach number.
- ICOND_i(ic_i) - Initial condition (ic) for analysis calculations.
See Table 9 for list of analysis initial conditions.
- [C]ONFIG(c) - Configuration to use for analysis.
Default is the highest or most recent.
- AIR - Atmosphere for hypersonic analysis.
HELIUM - Default is air.
CFFOUR - CF₄(carbon tetrafluoride).

-SET-/SET (concluded)

NOPRINT PRINT	- Diagnostic print for hypersonic runs. Increases output by a factor of ten. Default is NOPRINT.
SHKOFF SHKEXP	- Shock expansion indicator for hypersonic flap deflection calculations. Default is SHKOFF.
HYPOFF HYPER	- Hypersonic analysis indicator. Mach numbers less than 4.0 default to the subsonic-supersonic analysis unless the HYPER keyword is invoked. Default is HYPOFF. If HYPER keyword is invoked, it must be the last entry on the SET command string.
LINEAR FIXED	- Subsonic-supersonic source (thickness) solution indicator. Default is LINEAR. Experience has shown best results are obtained using FIXED for subsonic flows and LINEAR for supersonic conditions. Flap(s) must be at constant % chord when using the LINEAR option to avoid possible singularities (emanating from sonic leading edges) passing through control points on adjacent panels.

ABBREVIATION: None.

FUNCTION: Development of commonly used analysis variable lists. Up to twelve (12) can be stored in the user file. If SET subcommand is entered with no operands, the status of the present list is displayed and the user is prompted to fill the next available location.

EXAMPLE: Figure 4-11.

-SLENDER-

COMMAND: SLENDER

SLENDER,COMP(1)[,COMP(2),...COMP(16)][,FILE]

OPERANDS: COMP - Component(s) needed to form a slender body component.
Limit is sixteen (16).
Component numbers must be in same decade and numbered according to increasing x. Do not overlap components.

FILE - [P]ERMANENT; Default.
[L]OCAL
[C]OMPONENT

ABBREVIATION: SLEN

FUNCTION: Slender body construction.
Typically used to represent the fuselage, fuselage w/inlets and offset missile components.
Used in subsonic-supersonic analysis mode only.

Must use CATALOG command to store on file of choice.

LIMITS: Five (5) slender bodies per configuration.
(An offset slender body counts as one.)

Minimum number of sections is four (4) per slender body.

Maximum number of sections: (total for all geometry components to be used in forming a slender body component)
Twenty three (23) for TYPE 7 slender body.
Fourteen (14) for TYPE 8 slender body.

Solution sensitive to section placement. Best results are obtained when the Δx spacing between adjacent sections does not vary by more than a factor of two. Transition zones (places along the component where cross-sectional area changes suddenly become essentially constant) require more sections to adequately define cross-sectional area gradients.

$\Delta x/L < 0.001$ for area jumps (as when inlet(s) suddenly appear).
 $S(L) > 0.0$ required.

Control points cannot approach control points.
(Solution blows up).

In terms of slender body shape this means care must be exercised in modeling so that one surface is not parallel and in close proximity to another surface in the same cross-section. This situation typically arises in body closure or when blending inlets.

-SLENDER- (concluded)

PROMPT/RESPONSE:

```
      SLENDER-BODY SIMULATION
      ENTRY COMPONENT NAME
    +> slender body
      INPUT COMPONENT NUMBER
    +> 700.0
      COMPONENT PARAMETERS FOR SLENDER-BODY COMBINATION
      ENTER FACTOR,NPASS  [requested if offset body component present]
    +> 0.7, 3
```

FACTOR: Fraction of the segment length to the next point on the current section to use in finding the nearest surrounding point. Controls transition to an adjacent component as indicated in figure 3-71. Default is 0.7.

NPASS: Number of points to process on the new contour before starting the passing check again. It is used to prevent erroneous back linking. Default is 3.

EXAMPLE: Figures 3-70, 3-72.

-STATUS-

COMMAND: STATUS



STATUS

OPERANDS: None.

ABBREVIATION: ST

FUNCTION: Identifies the component number and name in core.

-TERMINAL-

COMMAND: TERMINAL



TERMINAL

OPERANDS: None.

ABBREVIATION: TERM

FUNCTION: Create simple geometry component using keyboard input.
 A common set of units must be used.

 Must use CATALOG command to store on file of choice.

EXAMPLE: Figures 3-16, 3-21, 3-38.

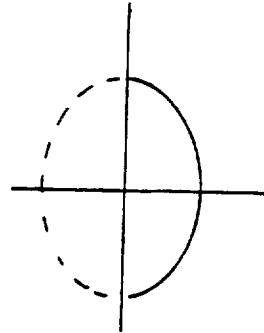
LIMITS: 10 Surface Sections.
 25 Body Sections.

GEOMETRY OPTION

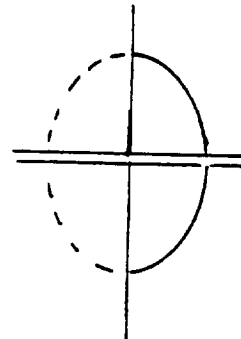
GEOMETRY

_____ STORED BOUNDARY
----- GENERATED BY SYMMETRY

3

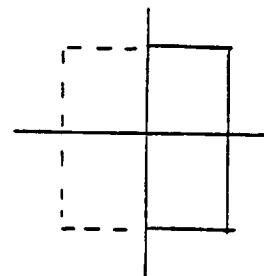


4



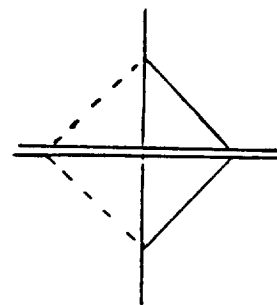
-4

5



6

-6



-TERMINAL- (continued)

PROMPTS:

ENTER COMPONENT YAW, PITCH, ROLL:

→→→ 0.0,0.0,0.0 [or <CR>]

* 1 FULL SURFACE (Uses 40 points per cross-section)
* 2 HALF SURFACE (Uses 40 points per cross-section)
* 3 FULL ELLIPSE (Variable number pts/cross-section. W/H=1=circle)
* +4 HALF ELLIPSE UP -4 HALF ELLIPSE DOWN (W/H=0.5=circle)
* 5 RECTANGLE
* +6 TRIANGLE UP -6 TRIANGLE DOWN
* E END

FULL SURFACE INPUT:

→→→ 1

INPUT COMPONENT NAME:

→→→ simple wing

INPUT COMPONENT NUMBER:

→→→ 101.

FULL SURFACE : X(ROOT),YO(ROOT),ZO(ROOT)

→→→ 33.02,3.30,-3.05

S,AR,TAPER,SWEEP(DEG),DIH(DEG): [$S \sim \text{in}^2$, cm^2 , or m^2]; [$\lambda > 0$]

→→→ 249.91,2.3,.2,45,3

* 1 65 A OXX (r/c=.639(t/c)**2)

* 2 64 A OXX (r/c=.686(t/c)**2)

* 3 SUPERCRITICAL

* 4 HEX AIRFOIL

* 5 BI-CONVEX

* SELECT AIRFOIL TYPE:

→→→ 1

ENTER : (T/C)1,...,(T/C)N,N<=10

(DEFAULT VALUES: 0.05,0.05)

→→→ 0.04,0.03 [or <CR>]; [0,0 for a flat plate]

OK

HALF SURFACE INPUT:

→→→ 2

INPUT COMPONENT NAME:

simple vertical

INPUT COMPONENT NUMBER:

→→→ 301.

HALF SURFACE :XO(ROOT),YO(ROOT),ZO(ROOT)

→→→ 33.02 0 3.56

-TERMINAL-(concluded)

```
      S,AR,TAPER,SWEEP(DEG),DIH(DEG): [S~in2, cm2, or m2]
--> 38.8 1.65 0.4 45 90
    * 1 65 A OXX      (r/c=.639(t/c)**2)
    * 2 64 A OXX      (r/c=.686(t/c)**2)
    * 3 SUPERCRITICAL
    * 4 HEX AIRFOIL
    * 5 BI-CONVEX
    * SELECT AIRFOIL TYPE:
--> 4
    ENTER : (T/C)1,...,(T/C)N,N<=10
            (DEFAULT VALUES: 0.05,0.05)
--> 0.03 0.03 [or <CR>]
    **OK**
```

BODY INPUT:

-->3

```
      INPUT COMPONENT NAME:
simple fuselage
      INPUT COMPONENT NUMBER:
--> 10.
```

```
      BODY COMPONENT
      XRO,YRO,ZRO      (origin of body)
--> 0.0 0.0 0.0 [or <CR>]
      NUMBER OF CROSS-SECTIONS OR
      X(1),A(1),W/H(1),...,X(NCS),A(NCS),W/H(NCS),NCS≤25
```

--> 5

ENTER SETS OF (X,A,W/H) FOR 5 CROSS SECTIONS

```
--> 5.59 0.0 0.88
?
--> 11.68 20.65 0.88 15.24 28.39 0.88
?
--> 33.02 30.97 0.88
?
--> 38.10 43.87 0.88
```

MAXIMUM HEIGHT ABOVE COMP. REF. LINE: 3.9836

MAXIMUM HALF WIDTH OF COMPONENT : 3.5055
OK

-TITLE-

COMMAND: TITLE

TITLE[,FILE]

OPERANDS: FILE - [P]ERMANENT; Default.
[L]OCAL

ABBREVIATION: TITL

FUNCTION: Input or change title of specified file.
Limit of 80 characters.

EXAMPLE: →→→ TITLE,L

PRESENT TITLE IS: APAS SAMPLE SESSION
ENTER: NEW TITLE OR 'CR'
→→→ <CR>

-UNITS-

COMMAND: UNITS

UNITS[,FILE]

OPERANDS: FILE - [P]ERMANENT; Default.
 [L]OCAL

ABBREVIATION: UNIT

EXAMPLE: →→→ unit
 PRESENT UNITS ARE: INCHES
 ENTER: 1 - METERS, 2 - INCHES, OR 3 - CENTIMETERS
 →→→ 1
 USER DEFAULT UNITS UPDATED TO MATCH FILE UNITS
 (THIS SESSION ONLY)

-VISCOUS-

COMMAND: VISCOUS

VISCOUS

OPERANDS: None.

ABBREVIATION: VISC

FUNCTION: Interactive viscous drag analysis. Perimeter and cross-sectional area distributions are generated for the configuration in the LOCAL file with the option to calculate viscous drag at specified conditions.

PROMPTS:

KEY * 1,2, OR 3

1 * PLOT * NX,X(1),...,X(NX)

2 * PLOT * NX,XB,XE

3 * PLOT WETTED SURFACE AREA AND VOLUME DISTRIBUTIONS

→→→ 3

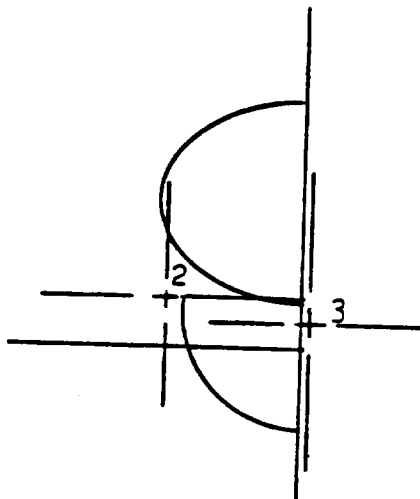
Options 1 and 2 are specialized features for configurations which do not have close control on wetted surface segments. No equivalent procedure exists in the background analysis.

Option 3 simulates the background viscous drag analysis. Surface area is evaluated using 51 cutting planes in the interactive analysis and component contour integration in the batch evaluation.

-VISCOUS- (continued)

OPTION 1:

DEMONSTRATION
SCALE=20.0
NX,X(1),...,X(NX)
→→ 2,200,300



The system asks for the number of section cuts ,NX, to make and the x-station values. The cursor (+) appears on the screen after each cross-section specified is displayed. Wetted line segments of the cut will appear solid, unwetted segments will appear dashed. To eliminate (make unwetted) unwanted line segments locate one end of the line segment and enter the numerical value corresponding to the location of the desired component in the local file. Move the cursor to the other end of the segment and enter the numerical value corresponding to the other component at this intersection. If none exists or the other component already has an unwetted line indicated, enter zero. When finished or if no segments need to be flagged, enter zero. Each pair of numbered entries eliminates a segment equivalent to that length from each indicated component. It is recommended that $NX \leq 5$ be used to keep the screen uncongested. When cross-section wetted perimeter corrections are completed, enter 0,0 in response to the "NX,X(1),...,X(N)" question.

OPTION 2:

Instead of answering: "NX,X(1),...,X(NX)", the question: "NX,XB,XE" where:

NX: Is the number of cross-section cuts to make between
XB: The beginning x-station and
XE: The ending x-station.

-VISCOUS- (continued)

OPTION 3:

Plots of perimeter and cross-sectional area are displayed using the cross hairs to separate pages. The system then responds with the following prompt:

0 EXIT
1 SF DRAG
2 EDIT

→→→ 1 (Default is 0)

For the EDIT option refer to option 1 described previously. The responses for the skin friction drag analysis for a body and surface are shown below.

SKIN FRICTION DRAG INPUT
INPUT MACH NUMBERS:

→→→ 0.6 1.2 1.6

INPUT SREF(M2)

→→→ 1250.

ENTER SAND GRAIN HEIGHT (KS(M))(DEFAULT:0.0)

→→→ 0.000021

ENTER [Stagnation values for] PRESS NT/M2,TEMP(K),LISTING MACH NUMBER
(0.0 FOR ALL) (DEFAULT IS NONE)

OR ENTER ALTITUDE, LISTING MACH NUMBER

ENTER CARRIAGE RETURN TO END:

→→→ 1221.,551.,0.6

→→→ 10000,1.2

→→→ <CR>

-VISCOUS- (continued)

SAMPLE BODY

ENTER: XTRANS/LENG, FLAT PLATE 1 * AXIS-BODY 2:

DEFAULT : 0.01,2

→→→ <CR>

SAMPLE SURFACE

ENTER: XTRANS/LENG, CK, FLAT PLATE 1 * AIRFOIL 2 :

DEFAULT : 0.01,1.2,2

→→→ 0.05,1.3,2

The sand grain height ,KS, in meters is the equivalent roughness of the configuration. See Table 11.

PFS is the static pressure in newtons/square meter, TFS is the static temperature in Kelvin. Altitude is in meters above sea level. The listing mach number is one of the input mach numbers at which a component break-down of viscous drag is desired.

XTRANS/LENG is the laminar transition point as a fraction of component length. CK is the airfoil linear thickness correction coefficient and accounts for surface curvature effects. See Table 12.

The system now blocks in and titles this page for copying. A page for each requested mach number is displayed followed by a summary page containing all the conditions run and tabulations of component wetted area and volumes.

EXAMPLE: Figure 4-4.

-VISCOUS- (concluded)

Table 11. Equivalent Sand Grain Roughness.

TYPE OF SURFACE	EQUIVALENT SAND GRAIN HEIGHT		
	METERS	INCHES	CENTIMETERS
AERODYNAMICALLY SMOOTH	0.0	0.0	0.0
POLISHED WOOD OR METAL	5.09×10^{-4} - 2.03×10^{-6}	0.02004 - 0.00008004	0.0509 - 0.000203
NATURAL SHEET METAL	3.96×10^{-6}	0.000156	0.000396
SMOOTH MATTE PAINT, CAREFULLY APPLIED	6.34×10^{-6}	0.000249	0.000634
STANDARD CAMOUFLAGE PAINT, AVERAGE APPLICATION	1.00×10^{-5}	0.0003996	0.000100
CAMOUFLAGE PAINT, MASS PRODUCTION SPRAY	3.05×10^{-5}	0.0012	0.00305
DIP-GALVANIZED METAL SURFACE	1.52×10^{-4}	0.0060	0.0152
NATURAL SURFACE OF CAST IRON	2.54×10^{-4}	0.009996	0.0254

Table 12. Airfoil Thickness Correction Factors.

AIRFOIL	THICKNESS CORRECTION (CK)
AIRFOIL t/c_{max} AT 30% CHORD	2.0
NASA 64 OR 65 SERIES AIRFOIL	1.2

-WAVEDRAG-

COMMAND: WAVEDRAG

WAVEDRAG

OPERANDS: None.

ABBREVIATION: WAVE

FUNCTION: Interactive wave drag analysis. Supersonic thickness drag is calculated for components currently attached in the local file.

PROMPTS:

ENTER SREF (M2)

→→→ 1255.0

ENTER MACH NUMBERS:

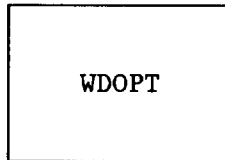
→→→ 1.2,1.6,2.0,2.2

A display of normal oblique projected cross-sectional area as a function of x-station and roll angle is displayed along with a tabulation of wavedrag as a function of roll angle and the total drag. The cross hairs appear on the screen when a case is completed. Pressing any key will initiate analysis of the next case.

EXAMPLE: Figures 4-8, 4-9, 4-10.

-WDOPT-

COMMAND: WDOPT



OPERANDS: None.

ABBREVIATION: None.

FUNCTION: ** WAVE DRAG OPTIMIZATION **

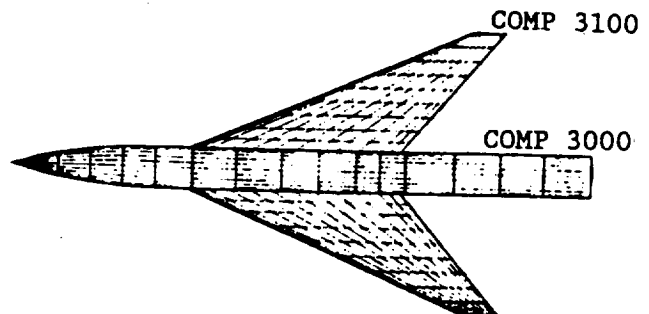
For configuration currently attached in the local file, user can select component(s) whose volume distribution will be redefined (while in the presence of the rest of the configuration) so that the configuration total wave drag will be an optimum (minimum).

PROMPT/RESPONSE:

Extensive user interaction required. The following example demonstrates some aspects of the command usage.

STEP 1: CLEAR, ATTACH Configuration to Local File, and Enter the Optimizer.

```
      **OK**
--> CL
      **OK**
--> ATTA 3000 3100
      **OK**
--> WDOPT
```



CONFIGURATION

STEP 2: Respond to Optimizer Prompts. See TFD-75-260 for Detailed Explanation of Terms (Theta Cuts, Harmonics, etc.)

OPTIMIZATION STRATEGY

Before responding to the following prompts a strategy should be worked out as a guide in the search of the optimum wave drag. In the present example it is desired to allow the fuselage volume (component 3000) to be redistributed in order to reduce the configuration wave drag. Also, rather than pursuing a point-design (optimize at one specific mach number) an average mach number solution is sought in the range $1.2 \leq M \leq 2.0$. Point-design optimization reduces wave drag locally but often produces higher wave drags at the off-design mach numbers, sometimes higher than the original configuration. The average mach number solution gives the user control over the distribution of the wave drag levels through the use of weight factors. This aspect will be discussed later. To invoke the average mach number solution one enters more than one mach number in response to the "INPUT SUPERSONIC MACH NUMBER(S)" prompt. In the present example three specific mach numbers will be input, i.e., 1.2, 1.6, and 2.0. However, before the average mach number solution mode can be entered the user must decide on what, if any, constraints will be imposed on the optimization process. The constraints must be held fixed for all mach numbers analyzed in the average mach number solution.

To evaluate the need for constraints an initial screening is undertaken by optimizing at each of the mach numbers using the point-design approach.

SECTION CONSTRAINTS

Section constraints are invoked when volume redistribution is indicated in an area where design changes are not permitted. The forward fuselage is often a restricted zone because of radar and canopy design requirements.

Responding to WDOPT prompts, the $M=1.2$ case is screened for section constraints. Note that the default value for NT is used. Higher values for NT are generally reserved for the final, detailed wave drag calculations (analysis run). The top and bottom body modification option is selected so that the wing mating juncture with the side of the fuselage will remain undisturbed. Thus, the maximum movement in the section redefinition occurs at the top and bottom centerline and diminishes to zero movement at the side of the section.

-WDOPT- (continued)

LOCAL FILE CONTENTS - - CONFIGURATION TO BE OPTIMIZED
 COMPONENT NO. NAME ITYPE ISYM

3000.00 NASA TN D-8361 B 1 2
 3100.00 NASA TN D-8361 W 4 2

INPUT SUPERSONIC MACH NUMBER(S) (RETURN - ENDS SESSION)
 +>>> 1.2
 INPUT SREF(IN2):
 +>>> 1290
 INPUT NT: NT(MAXIMUM)=25
 NT(DEFAULT)= 5
 NT = NUMBER OF THETA CUTS
 FOR SYMMETRICAL CONF FOR ASYMMETRIC CONF
 (-90 TO +90) (-90 TO =270)
 5=45 DEG, 13=15 DEG 5=90 DEG, 13=30 DEG
 19=10 DEG, 25=7.5DEG 19=20 DEG, 25=15 DEG
 +>>> <CR>
 INPUT COMPONENT NUMBER(S) TO BE OPTIMIZED
 COMP. NO.S ENTERED MUST ALL BE FOR GROUP ITYPE 1,2 OR 3,4
 (RETURN = ANALYSIS RUN ONLY)
 +>>> 3000
 FOR BODY MODIFICATION(1&2): FOR WING MODIFICATION(3&4)
 ENTER: 0 TOP AND BOTTOM 0 T/C CHANGED SPANWISE
 1 TOP ONLY 1 T/C CHANGED CHORDWISE
 2 BOTTOM ONLY
 3 SIDE ONLY
 +>>> 0

At this point the cross hairs have appeared on the screen. Hit the spacebar to continue.

The next set of prompts that appear are shown below. The number of harmonics specified should not exceed the number of sections in a component. One harmonic is required to modify one component section. Be sure your component(s) have ample sections, well spaced, so that potential movements can be made.

INPUT NUMBER OF HARMONICS FOR AXIAL COVERAGE OF BODY (ITYPE=1,2)
 DEFAULT = 8
 LIMIT = 20
 +>>> 15
 INPUT: XSTART,XEND (DEFAULT: 0.0 HOLDS FIRST AND LAST SECTION OF EACH COMPONENT)
 TO ALTER FIRST AND/OR LAST SECTION OF A COMPONENT
 ENTER: XSTART-? AND/OR XEND+?
 OVERALL EXTENT OF COMPONENT(S) TO BE OPTIMIZED IS:
 XSTART = -1.00 XEND= 106.41
 +>>> <CR>

-WDOPT- (continued)

After the above carriage return has been entered, a long pause generally occurs before the cross hairs appear once again on the screen. The code is solving the matrix of equations represented by the sum of the number of thetas, harmonics, and constraints. Computation time is a direct function of this sum. The sum of the number of harmonics and constraints must not exceed 41.

The results of the solution are shown next. The solution is for a delta volume constraint of zero. This means that if volume is removed in one location (as in the forward fuselage) it must be added in other locations (most goes to aft fuselage in this case) so that the net change in volume addition and subtraction is zero. The delta volume constraint will be discussed in more detail latter.

The wave drag summary for each of the five theta cuts (90 degrees = top centerline) shows that the optimizer was able to about halve the wave drag. The geometry data shown record the optimized and unoptimized values. The side view of the fuselage shows the "coke bottle" effect produced by the linearized theory supersonic area rule algorithm in the optimizer.

WDOPT: WAVE DRAG OPTIMIZATION EXAMPLE

MACH= 1.200

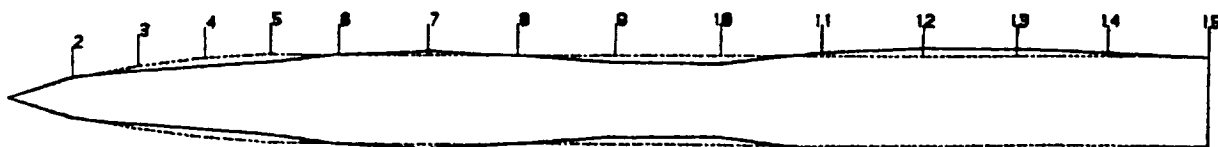
DELTA VOLUME= 0.0

<u>NO.</u>	<u>THETA</u>	<u>D/Q</u>	<u>OPT D/Q</u>
1	90.00	7.67	4.40
2	45.00	7.70	4.12
3	0.0	8.27	4.50
4	-45.00	7.70	4.12
5	-90.00	7.67	4.40
** TOTAL WAVE DRAG COEFFICIENT		0.0061	0.0033

<u>SECT</u>	<u>OPT T</u>	<u>OLD R</u>	<u>X</u>
1	0.000	0.000	0.0
2	1.794	1.685	5.000
3	2.293	2.694	11.600
4	2.730	3.417	17.400
5	3.153	3.810	23.190
6	3.870	3.810	29.244
7	4.203	3.810	37.152
8	3.786	3.810	45.183
9	3.192	3.810	53.709
10	3.113	3.810	62.852
11	4.144	3.810	71.748
12	4.523	3.810	80.844
13	4.447	3.810	88.923
14	4.153	3.810	96.830
15	3.810	3.810	105.410

----- unoptimized geometry

_____ optimized geometry



-WDOPT- (continued)

In the next set of prompts the example problem requires that the forward fuselage remain unmodified. In other words the forward fuselage modification made by the optimizer is considered unacceptable because of design considerations (canopy, radar, etc.). Section constraints will be imposed on sections 2 thru 6 as shown below.

```

INPUT: DELTA VOLUME (DEFAULT=0)
--> <CR>
INPUT: SECTION NUMBER(S) TO BE CONSTRAINED (DEFAULT=0)
--> 2 3 4 5 6
INPUT: R-VALUE(S). R<0 REMOVES CONSTRAINT AT THAT SECTION
--> 1.685 2.694 3.417 3.810 3.810
  
```

Constraint additions/changes are not computationally time consuming because the influence coefficient matrix has already been computed for the x-cuts, theta-cuts, and harmonic (or modal shape) specifications. The optimization results with the section constraints are shown next. Note that the new optimized value is 11 counts higher than the previous unconstrained result. However, the constrained value is 28% lower than the unoptimized configuration. Note that once a section constraint has been specified, it remains in effect. To remove a section constraint, input the section number and then input a R<0 value when prompted for R.

WDOPT: WAVE DRAG OPTIMIZATION EXAMPLE

MACH= 1.200 DELTA VOLUME= 0.0

NO.	THETA	D/Q	OPT D/Q
1	90.00	7.67	5.89
2	45.00	7.70	5.56
3	0.0	8.27	5.81
4	-45.00	7.70	5.56
5	-90.00	7.67	5.89
** TOTAL WAVE DRAG COEFFICIENT		0.0061	0.0044

SECT	OPT T	OLD R	X
1	0.000	0.000	0.0
2	1.685	1.685	5.000
3	2.694	2.694	11.600
4	3.417	3.417	17.400
5	3.810	3.810	23.190
6	3.810	3.810	29.244
7	4.064	3.810	37.152
8	3.625	3.810	45.183
9	3.034	3.810	53.709
10	2.969	3.810	62.852
11	4.014	3.810	71.748
12	4.412	3.810	80.844
13	4.366	3.810	88.923
14	4.109	3.810	96.830
15	3.810	3.810	105.410

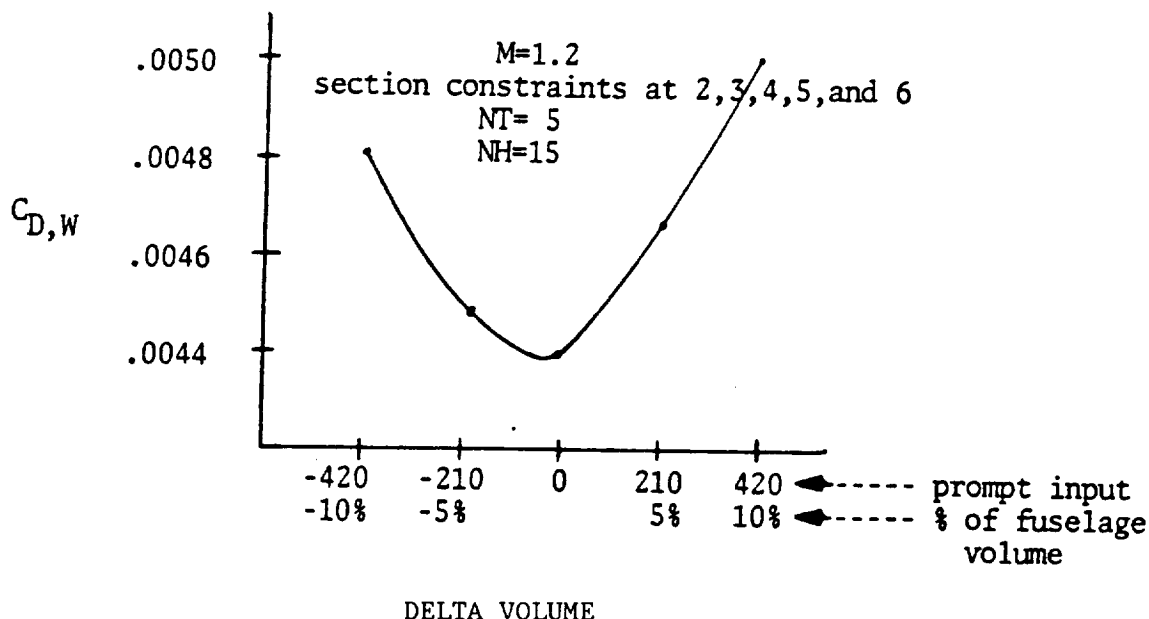
----- unoptimized geometry

_____ optimized geometry



DELTA VOLUME CONSTRAINTS

The effect of adding or removing volume in the fuselage component on the above optimum wave drag is shown in the following plot. In this particular case a delta volume of zero is the optimum and this is true for $M=1.6$ and 2.0 as well. In screening a more complicated configuration one might expect to find different values of delta volume produce the minimum point, at the different mach numbers. In that event one must decide on an average value to use since only one value must be invoked during the average mach number solution process.



To end the constraint prompt loop one accepts the default values as shown below. The next prompt wants to know whether to save the optimized component geometry into the local file. For the purposes of this example the local file geometry is not to be updated at this time since the result stored would be for the $M=2.0$ point-design optimum. The code then moves the user back to the beginning, where the mach number(s) are specified, etc.

```

INPUT: DELTA VOLUME (DEFAULT=0)
+++ <CR>
INPUT: SECTION NUMBER(S) TO BE CONSTRAINED (DEFAULT=0)
+++ <CR>
    1=SAVE OPT. COMP; 0=NO (DEFAULT=NO)
+++ <CR>

```

AVERAGE MACH NUMBER SOLUTION

The average mach number solution algorithm is invoked by entering more than one mach number as shown below. The weight factors associated with each mach number is also requested. Once the solution is computed the user can respecify the weight factors to study this influence and to a certain extent have control over the shaping of the level of the wave drag as a function of mach number. Studying the influence of weight factor is inexpensive and the user should feel free to explore a variety of combinations. The inputs for reference area, number of theta-cuts, component to be optimized, nature of body modification and the number of harmonics remains the same as before. After this input the code provides the unconstrained wave drag optimum for the first mach number ,i.e., M=1.2.

```
      INPUT SUPERSONIC MACH NUMBER(S) (RETURN - ENDS SESSION)
--> 1.2 1.6 2.0
      INPUT WEIGHT FACTOR FOR EACH MACH NO. TO BE USED IN AVERAGE MACH NUMBER
      SOLUTION
--> 1 1 1
```

The next screen, shown below, prompts the user to specify the constraints to be used for all the mach numbers. All future prompts for this information should be answered by accepting the defaults, i.e., input a carriage return.

```
      SPECIFY CONSTRAINTS TO BE USED FOR ALL MACH NUMBERS
      INPUT: DELTA VOLUME (DEFAULT=0)
--> <CR>
      INPUT: SECTION NUMBER(S) TO BE CONSTRAINED (DEFAULT=0)
--> 2 3 4 5 6
      INPUT: R VALUE(S), R<0 REMOVES CONSTRAINT AT THAT SECTION
--> 1.685 2.694 3.417 3.81 3.81
```

The code then reanalyzes the M=1.2 case and provides the output. Continuing to respond to the prompts as they come up the code will proceed to analyze the M=1.6 and 2.0 cases as shown next.

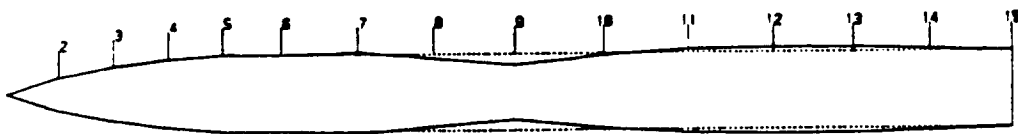
-WDOPT- (continued)

WDOPT: WAVE DRAG OPTIMIZATION EXAMPLE

MACH= 1.200 DELTA VOLUME= 0.0

<u>NO.</u>	<u>THETA</u>	<u>D/Q</u>	<u>OPT D/Q</u>
1	90.00	7.42	6.83
2	45.00	8.69	6.45
3	0.0	8.02	6.11
4	-45.00	8.69	6.45
5	-90.00	7.42	6.83
** TOTAL WAVE DRAG COEFFICIENT		0.0064	0.0050

<u>SECT</u>	<u>OPT T</u>	<u>OLD R</u>	<u>X</u>	
1	0.000	0.000	0.0	
2	1.685	1.685	5.000	
3	2.694	2.694	11.600	
4	3.417	3.417	17.400	
5	3.810	3.810	23.190	
6	3.810	3.810	29.244	
7	4.064	3.810	37.152	
8	3.625	3.810	45.183	----- unoptimized geometry
9	3.034	3.810	53.709	
10	2.969	3.810	62.852	_____ optimized geometry
11	4.014	3.810	71.748	
12	4.412	3.810	80.844	
13	4.366	3.810	88.923	
14	4.109	3.810	96.830	
15	3.810	3.810	105.410	



-WDOPT- (continued)

WDOPT: WAVE DRAG OPTIMIZATION EXAMPLE

MACH= 1.200 DELTA VOLUME= 0.0

<u>NO.</u>	<u>THETA</u>	<u>D/Q</u>	<u>OPT D/Q</u>
1	90.00	7.13	7.93
2	45.00	7.79	6.20
3	0.0	7.70	7.17
4	-45.00	7.79	6.20
5	-90.00	7.13	7.93

** TOTAL WAVE DRAG COEFFICIENT

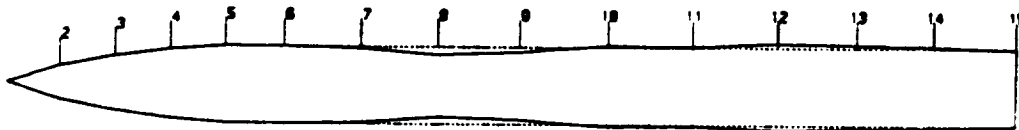
0.0059

0.0052

<u>SECT</u>	<u>OPT T</u>	<u>OLD R</u>	<u>X</u>
1	0.000	0.000	0.0
2	1.685	1.685	5.000
3	2.694	2.694	11.600
4	3.417	3.417	17.400
5	3.810	3.810	23.190
6	3.810	3.810	29.244
7	4.064	3.810	37.152
8	3.625	3.810	45.183
9	3.034	3.810	53.709
10	2.969	3.810	62.852
11	4.014	3.810	71.748
12	4.412	3.810	80.844
13	4.366	3.810	88.923
14	4.109	3.810	96.830
15	3.810	3.810	105.410

----- unoptimized geometry

_____ optimized geometry



The following summary output is provided by the code and shows the wave drag levels as a function of mach number for the weight factors selected as well as the corresponding geometry valid for the mach number range. In the present example it is assumed that the $M = 2.0$ wave drag will be reduced as much as possible. To accomplish this, new weight factors are entered to favor the $M = 2.0$ case.

-WDOPT- (continued)

WDOPT: WAVE DRAG OPTIMIZATION EXAMPLE

MACH=	1.200	DELTA VOLUME=	0.0
NO.	THETA	D/Q	
1	-90.00	6.251	
2	-45.00	5.865	
3	0.0	5.964	
4	45.00	5.868	
5	90.00	6.250	
** TOTAL WAVE DRAG COEFFICIENT		0.0046	

WDOPT: WAVE DRAG OPTIMIZATION EXAMPLE

MACH=	1.600	DELTA VOLUME=	0.0
NO.	THETA	D/Q	
1	-90.00	5.965	
2	-45.00	6.607	
3	0.0	7.101	
4	45.00	6.606	
5	90.00	5.966	
** TOTAL WAVE DRAG COEFFICIENT		0.0051	

WDOPT: WAVE DRAG OPTIMIZATION EXAMPLE

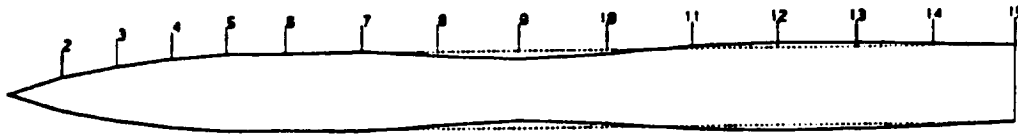
MACH=	2.000	DELTA VOLUME=	0.0
NO.	THETA	D/Q	
1	-90.00	6.146	
2	-45.00	6.746	
3	0.0	9.817	
4	45.00	6.748	
5	90.00	6.145	
** TOTAL WAVE DRAG COEFFICIENT		0.0056	

OPTIMIZED GEOMETRY (SOLID) USING AVERAGE MACH NUMBER SOLUTION

MACH	WEIGHT
1.20	1.00
1.60	1.00
2.00	1.00

-WDOPT- (continued)

<u>SECT</u>	<u>OPT T</u>	<u>OLD R</u>	<u>X</u>	
1	0.000	0.000	0.0	
2	1.685	1.685	5.000	
3	2.694	2.694	11.600	
4	3.417	3.417	17.400	
5	3.810	3.810	23.190	
6	3.810	3.810	29.244	
7	4.064	3.810	37.152	
8	3.625	3.810	45.183	----- unoptimized geometry
9	3.034	3.810	53.709	
10	2.969	3.810	62.852	----- optimized geometry
11	4.014	3.810	71.748	
12	4.412	3.810	80.844	
13	4.366	3.810	88.923	
14	4.109	3.810	96.830	
15	3.810	3.810	105.410	



WOULD YOU LIKE TO TRY A DIFFERENT WEIGHT ON MACH NUMBERS?
PRESENT VALUES ARE (MACH,WEIGHT)

1.20 1.00
1.60 1.00
2.00 1.00

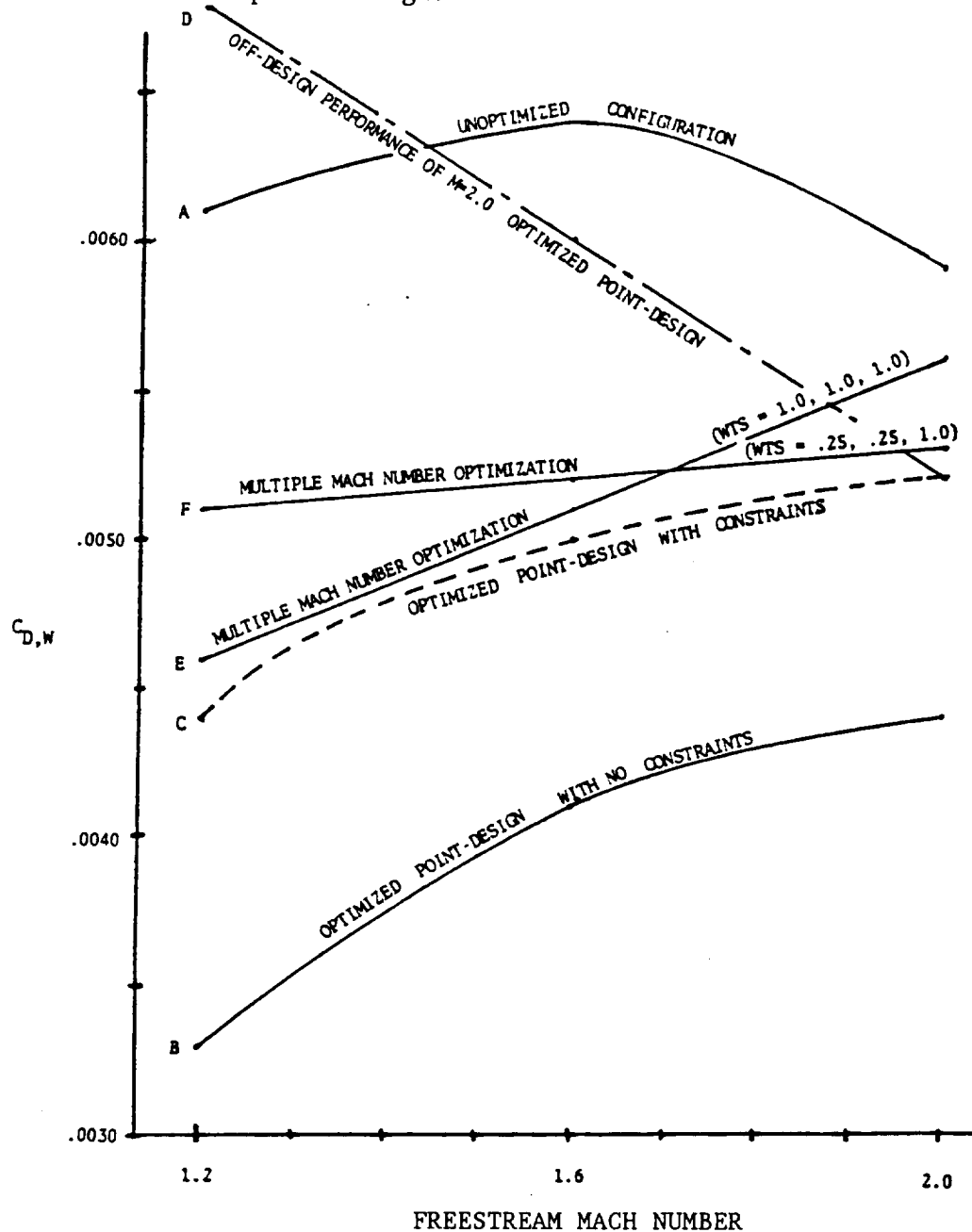
1=YES 0=NO (DEFAULT=NO)

→→→ 1

INPUT WEIGHT FACTOR FOR EACH MACH NUMBER TO BE USED IN AVERAGE MACH
NUMBER SOLUTION

→→→ .25 .25 1.

The following graph summarizes the various results obtained in the course of this example problem. The difference between curves A and B show the maximum wave drag reduction that could be possible. More realistic is curve C since geometry constraints are almost always a certainty. The problem of point-design optimization is demonstrated in curve D and shows the poor off-design performance at other mach numbers. Curves E and F indicate the reason for a bias towards using an average mach number solution rather than the point-design.



OTHER FEATURES

The above example demonstrated one branch of the wave drag optimizer. Within the context of that example a top, bottom or side only body modification option could have been explored in the search for a better optimum. Generally the choice selected is governed more by hardware construction and/or boundary layer control considerations than by pure academic optimizations.

Experience has shown some small benefit can be realized if one now proceeds to optimize the wing in the presence of the optimized(saved) body in the above example. For the wing modification (surface components = Types 3&4) the user can vary the thickness (T/C) spanwise or airfoil shape (T/C) chordwise. The spanwise option works best. Be sure to enrich your wing component with additional sections, especially in the root area, because the optimizer tends to produce blended wing-body designs.

Negative areas are often produced when using the chordwise option, forcing the user to impose many constraints on the solution. Generally so little volume is available in the wing that its redistribution causes severe changes in the wing section shape. Since the wing section design is more constrained by other aspects of aerodynamics than wave drag considerations this option should have restricted usage. Possibly in the design of a flying wing where all the volume is in the wing.

LIMITS: NT = NUMBER OF THETA-CUTS = 25

NUMBER OF HARMONICS + NUMBER OF CONSTRAINTS = 41

APPENDIX A

CARD COMMAND INPUT DESCRIPTION

Vehicle body, surface, and field point data can be entered in card image form using the input format described in this appendix. The card image data set should be stored under an appropriate data set name on user's computer resident catalog for later reference by APAS.

Data set access and transfer to the local or permanent file is accomplished using the CARD command of section 6.

Header Card for CARD Command Input File

NUMBER		IDENT	DESCRIPTION	DO NOT KEY PUNCH
T	ITLE OF GEO	1-12	Title (72 characters)	
M	ENTRY FILE	13-24		
		25-36		
		37-48		
		49-60		
		61-72		
	20	1-12		
	3.0	13-24	NC - No. of Components (≤ 50)	
	100.0	25-36	Component Number 1	
	300.0	37-48		
	1200.0	49-60		
		61-72		
-	70	1-12	Up Through	
		13-24	Component Number 50	
		25-36	If Desired	
		37-48	(Last card before first component data must have a	
		49-60	minus sign in column 1)	
		61-72		
		1-12		
		13-24		
		25-36		
		37-48		
		49-60		
		61-72		

General Procedure for Inputing BODY Components That Mimick TERMINAL Command

NUMBER		IDENT	DESCRIPTION	DO NOT KEY PUNCH
	100.00	1-12	Component Number (≥ 10)	
F	USELAGE	13-24	Component Name (≤ 16 Characters)	
		25-36		
		37-48		
		49-60		
		61-72		
	100	1-12		
	18.0	13-24	NCS	Number of cross-sections (≤ 18)
	0.0	25-36	Xo	Relative Orgin of Component
	0.0	37-48	Yo	
	0.0	49-60	Zo	
	3.0	61-72	C (3.0=Full Ellipse, ± 4.0 Half Ellipse, etc.) TYPE (See TERMINAL command)	
	105	1-12	RLC	Relative Location for start of first section
	0.0	13-24	A1 Cross-sectional Area	
	0.0	25-36	D1 h/2 (Full height of Δ , and semi-circle)	
	0.0	37-48	XR	Section Orgin Relative to Xo,Yo,Zo
	0.0	49-60	YR	
	0.0	61-72	ZR	
-	190	1-12	RLC + NCS*5 (Locations 105-195 are for section data)	
	500.0	13-24	A	NCS
	12.62	25-36	D	
	741.0	37-48	XR	NCS
	0.0	49-60	YR	
-	6.2	61-72	ZR	

General Procedure for Inputing SURF Components That Mimick TERMINAL Command

NUMBER	IDENT	DESCRIPTION	DO NOT KEY PUNCH
300.00	1-12	Component Number (≥ 10)	
W ING	13-24	Component Name (≤ 16 Characters)	
	25-36		
	37-48		
	49-60		
	61-72		
100	1-12		
2.0	13-24	NCS Number of Cross-Sections (≤ 17 Sections)	
0.0	25-36	Xo	}
0.0	37-48	Yo	
0.0	49-60	Zo	
1.0	61-72	C (1.0=Full Surface, 2.0=Half Surface, etc.) TYPE (See TERMINAL command)	
105	1-12		
2.0	13-24	Airfoil Type (1.0=65A; 2.0=64A; etc.; 0.0=General)	
0.0	25-36	Upper Surface Flag	If Airfoil Type=0.0, Set=1.0
0.0	37-48	Lower Surface Flag	If Airfoil Type=0.0, Set=1.0 If also symmetric, Set=0.0
	49-60	No. x/c's	If Airfoil Type=0.0, Input
	61-72		
110	1-12		
4.0	13-24	AR	
350.00	25-36	S	
0.34	37-48	TAPER	
55.0	49-60	SWEEP	
0.0	61-72	DIHEDRAL	

General Procedure for Inputing SURF Components (Concluded)

NUMBER	IDENT	DESCRIPTION	DO NOT KEY PUNCH
115	1-12	RLC	Relative Location for start of section data
0.60	13-24	T/C MAX	Consecutively One
210.0	25-36	CHORD	Card Per Cross-Section
165.0	37-48	XR	} 2nd section RLC=120 3rd, RLC=125 etc.
23.0	49-60	YR	
0.0	61-72	ZR	
200	1-12	RLC	200-219 are for x/c's
0.0	13-24	x/c 1	Fill in only if Upper Surface Flag is > 0.0
0.1	25-36	x/c 2	
0.2	37-48	x/c 3	
0.3	49-60	x/c 4	
etc.	61-72	etc.	
211	1-12		
1.0	13-24	x/c 11	Note: Up to 20 x/c's may be specified.
	25-36		
	37-48		
	49-60		
	61-72		
220	1-12	RLC	from 220 to 499 are for upper and lower
0.0	13-24		surface z/c's. The upper z/c's of one section
0.002	25-36		are followed directly by the z/c's for the
0.008	37-48		lower surface. [If RLC=107 is zero, and airfoil
etc.	49-60		is symmetric, enter upper surface z/c's only]
	61-72		Input only one section if all have same z/c's (Fill in only if upper surface flag is >0.0)

General Procedure for Inputing FIELD POINT Component

NUMBER		IDENT	DESCRIPTION	DO NOT KEY PUNCH
	1200.00	1-12	Component Number (≥ 10)	
F	IELD POINTS	13-24	Component Name (≤ 16 characters)	
		25-36		
		37-48		
		49-60		
		61-72		
	100	1-12		
	10.0	13-24	NPOINTS = Number of Field Points (≤ 100)	
		25-36	$110 \leq x < 240$	
		37-48	$240 \leq y < 370$	
		49-60	$370 \leq z < 500$	
	9.0	61-72	C	TYPE
	110	1-12		
-	100.0	13-24	x	1
-	50.0	25-36		
	50.0	37-48		
	100.0	49-60		
	150.0	61-72		
	115	1-12	NPOINTS + 105	
		13-24		
		25-36		
		37-48		
		49-60		
	1000.0	61-72	x	NPOINTS

General Procedure for Inputing FIELD POINT Component (concluded)

NUMBER	IDENT	DESCRIPTION	DO NOT KEY PUNCH
240	1-12	RLC	(240 ≤ Locations < 370 reserved for y-values)
100.0	13-24	y ₁	
100.0	25-36	y ₂	
100.0	37-48	y ₃	
100.0	49-60	•	
100.0	61-72	•	
245	1-12	NPOINTS + 235	
100.0	13-24	•	
100.0	25-36	•	
100.0	37-48	•	
100.0	49-60	•	
100.0	61-72	y NPOINTS	
370	1-12	RLC	(370 ≤ Locations < 500) for z-values
50.0	13-24	z ₁	
50.0	25-36	z ₂	
50.0	37-48	•	
50.0	49-60	•	
50.0	61-72	•	
- 375	1-12	NPOINTS + 365	
50.0	13-24	•	
50.0	25-36	•	
50.0	37-48	•	
50.0	49-60	•	
50.0	61-72	z NPOINTS	

GEOMETRY FILE TITLE

	20	3.00	100.0	300.0	1200.0	
-	100.0	FORWARD	FUSELAGE			
	100	8.00	0.00	0.00	0.00	3.00
	105	0.00	0.00	0.00	0.00	0.00
	110	78.00	5.00	15.00	0.00	4.00
	115	210.00	8.25	30.00	0.00	8.00
	120	386.00	11.10	50.00	0.00	11.00
	125	490.00	13.00	78.00	0.00	13.00
	130	1020.00	25.00	95.00	0.00	7.00
	135	1758.00	28.00	115.00	0.00	8.50
-	140	1900.00	29.00	130.00	0.00	9.00
	300.0	INBOARD	WING			
	100	5.00	0.00	18.00	-8.00	1.00
	105	0.00	1.00	1.00	11.00	0.00
	110	1.00	100.00	0.00	70.00	0.00
	115	0.11	800.00	0.00	0.00	0.00
	120	0.12	726.00	74.00	12.00	0.00
	125	0.13	633.00	167.00	24.00	0.00
	130	0.14	500.00	300.00	36.00	0.00
	135	0.17	400.00	400.00	48.00	0.00
	200	0.00	0.10	0.20	0.30	0.40
	205	0.50	0.60	0.70	0.80	0.90
	210	1.00				
	220	0.0000	0.0219	0.0563	0.0588	0.0569
	225	0.0550	0.0538	0.0544	0.0569	0.0606
	230	0.0625	0.0000	0.0094	0.0156	0.0213
	235	0.0275	0.0338	0.0400	0.0463	0.0525
	240	0.0325	0.0031	0.0062	0.0372	0.0606
	245	0.0592	0.0585	0.0572	0.0565	0.0572
	250	0.0599	0.0620	0.0640	-0.0062	0.0110
	255	0.0193	0.0262	0.0331	0.0393	0.0455
	260	0.0517	0.0585	0.0324	0.0021	0.0174
	265	0.0521	0.0553	0.0553	0.0545	0.0537
	270	0.0550	0.0537	0.0585	0.0569	0.0537
	275	-0.0174	0.0126	0.0237	0.0316	0.0395
	280	0.0458	0.0521	0.0585	0.0585	0.0284
	285	0.0000	-0.0080	0.0140	0.0240	0.0360
	290	0.0480	0.0590	0.0640	0.0660	0.0650
	295	0.0620	0.0570	0.0800	0.0280	0.0370
	300	0.0460	0.0520	0.0590	0.0660	0.0720
	305	0.0500	0.0210	-0.0070	-0.0075	0.0313
	310	0.0438	0.0563	0.0663	0.0800	0.0825
	315	0.0825	0.0800	0.0750	0.0713	0.0075
	320	0.0425	0.0488	0.0550	0.0613	0.0825
-	325	0.0875	0.0775	0.0488	0.0188	0.0100
	1200.0	FIELD	POINTS			
	100	10.00				9.00
	110	-100.00	-50.00	50.00	100.00	150.00
	115	200.00	400.00	600.00	800.00	1000.00
	150	100.00	100.00	100.00	100.00	100.00
	155	100.00	100.00	100.00	100.00	100.00
	200	50.00	50.00	50.00	50.00	50.00
-	205	50.00	50.00	50.00	50.00	50.00

Listing of Keyed-In CARD Data Following Format Shown on Previous Pages

General Procedure for Inputing a BODY Component That Has a General Section

NUMBER		IDENT	DESCRIPTION	DO NOT KEY PUNCH
	1001.00	1-12	Component Number (≥ 10)	
G	EN FUS CARD	13-24	Component Name (≤ 16 Characters)	
S		25-36		
		37-48		
		49-60		
		61-72		
	100	1-12		
	3.0	13-24	NCS	Number of cross-sections (≤ 18)
	0.0	25-36	Xo	Relative Orgin of Component
	0.0	37-48	Yo	
	0.0	49-60	Zo	
-	1.0	61-72	C TYPE	(-1.0 General section input expected)
	105	1-12	RLC	Relative Location for start of first section
	17.0	13-24	NPH	Number of points per cross-section
	4.0	25-36	NX	Number of segments per cross-section
	8.0	37-48	NX 1	Number of points in 1st segment
	2.0	49-60	NX 2	Number of points in 2nd segment
	2.0	61-72	•	Etc. Ten segments is max
-	115	1-12	RLC + NCS*5 (Locations 105-195 are for section data)	
	6.858	13-24	x 1	First section (x-held fixed)
	0.0	25-36	y 1	All the y's are input next,
	0.573	37-48	y 2	followed by all the z's.
	1.089	49-60	y 3	
-	1.410	61-72	y 4	Etc. (See complete data set on next page)

GENERAL FUSELAGE EXAMPLE

-	20	1.00	1001.0			
	1001.0	GEN FUS CARDS				
	100	3.00	0.00	0.00	0.00	-1.00
	105	17.00	4.00	8.00	2.00	2.00
	110	5.00				
	115	6.858	0.000	0.573	1.089	1.410
	120	1.707	1.989	2.274	2.518	2.518
	125	2.464	2.464	2.456	2.456	1.990
	130	1.493	0.958	0.000	2.516	2.461
	135	2.311	1.947	1.606	1.226	0.911
	140	0.501	0.501	-1.962	-1.962	-2.314
	145	-2.314	-2.697	-2.880	-2.986	-3.067
	150	8.382	0.000	0.537	1.026	1.446
	155	1.780	2.097	2.359	2.632	2.632
	160	2.621	2.621	2.608	2.608	2.059
	165	1.542	0.988	0.000	2.515	2.485
	170	2.384	2.200	1.932	1.618	1.314
	175	0.950	0.950	-1.917	-1.917	-2.521
	180	-2.521	-2.812	-2.999	-3.064	-3.119
	185	10.719	0.000	0.496	0.950	1.358
	190	1.721	2.083	2.365	2.641	2.641
	195	2.624	2.624	2.604	2.604	2.035
	200	1.510	0.965	0.000	2.515	2.482
	205	2.395	2.269	2.115	1.912	1.677
	210	1.352	1.352	-1.766	-1.766	-2.722
-	215	-2.722	-2.934	-3.037	-3.097	-3.118

Listing of Keyed-In CARD Data Following Format Shown on Previous Page

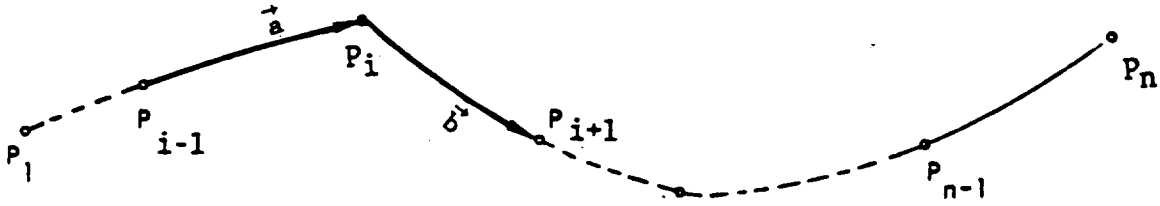
APPENDIX B

POINT SPACING, INTERPOLATION, AND GEOMETRY TRANSFORMATIONS

Point spacing and data interpolation procedures are defined. A summary of the transformations used to position and display geometry are presented.

POINT SPACING

Given a set of ordered input points in three space, the angle between two consecutive vectors \vec{a} and \vec{b} can be determined as follows:



$$\cos \theta_i = \vec{a} \cdot \vec{b} / [|\vec{a}| |\vec{b}|] \quad 2 \leq i \leq n-1$$

where

$$\vec{a} = a_1 \vec{i} + a_2 \vec{j} + a_3 \vec{k}$$

$$\vec{b} = b_1 \vec{i} + b_2 \vec{j} + b_3 \vec{k}$$

Thus

$$\theta_i = \cos^{-1} \left[[a_1 b_1 + a_2 b_2 + a_3 b_3] / [a_1^2 + a_2^2 + a_3^2] [b_1^2 + b_2^2 + b_3^2]^{1/2} \right]$$

The end points are arbitrarily defined as $\theta_1=0$ and, $\theta_n = \theta_{n-1}$. A rule for spacing points based on the total angular displacement can be developed such that the angular change between any two vectors is a constant. That is:

$$\Delta\theta = \text{constant}$$

$$\theta = \sum_{i=1}^n |\theta_i|$$

Alternatively, a constant incremental arc length rule can be considered

$$\Delta S/S = \text{constant}$$

$$S_1 = 0$$

$$S = \sum_{i=2}^n \left[[x_i - x_{i-1}]^2 + [y_i - y_{i-1}]^2 + [z_i - z_{i-1}]^2 \right]^{1/2}$$

A spacing algorithm (SPCTOL) was designed considering either or both properties. It is used with a 0.5 property bias to space points on digitized body cross sections and during hypersonic model generation.

INTERPOLATION

There are three methods of curve fitting geometry data and one method for curve fitting analysis display data. They are linear, second order and least squares smoothing. The second order routine is also used for analysis data.

The linear curve fit solves the equation.

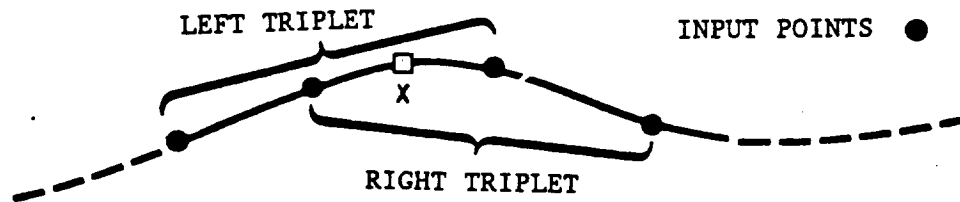
$$y = y_n + (y_{n+1} - y_n)(x - x_n) / (x_{n+1} - x_n)$$

$$\text{where } x_n \leq x \leq x_{n+1}.$$

The second order curve fit solves the equation

$$\begin{aligned} y = & (x - x_n)(x - x_{n+1}) / [(x_{n-1} - x_n)(x_{n-1} - x_{n+1})] y_{n-1} \\ & + (x - x_{n-1})(x - x_{n+1}) / [(x_n - x_{n-1})(x_n - x_{n+1})] y_n \\ & + (x - x_{n-1})(x - x_n) / [(x_{n-1} - x_{n+1})(x_{n+1} - x_n)] y_{n+1} \end{aligned}$$

for the value y . The evaluation is performed first for a left triplet, then the right triplet. The two resulting y 's are averaged.



A least squares curve fit solves for the coefficients a_1, a_2, \dots, a_n in the equation

$$z = \sqrt{2rx(1-x)} + x(1-x) [a_1 + a_2 x + \dots + a_{n-1} x^{n-2}] + xz_t \quad 0 \leq x \leq 1$$

such that the error $\sum_{i=1}^n (z - z_i)^2$ is a minimum in the least squares sense under the condition that the curve passes exactly through the first and last points. r is taken as the initial normalized radius of curvature and z_t is the normalized maximum half thickness. The input data is prepared such that the first point passes through $z=0$, and the last point passes through $z=z_t$. The value of r can be input or can be solved for as an additional unknown coefficient a_n

$$r = a_n^2 / 2$$

When r and z_t are set to zero, a standard least squares fit, results. This form is used for digitized body sections.

The principle purpose of this routine, is to smooth airfoil data being input through the digitizer.

GEOMETRY TRANSFORMATIONS

Consider two orthogonal reference systems μ and ν . The transformation from μ to ν is defined by

$$[x \ y \ z \ h]_{\nu} = [x \ y \ z \ h]_{\mu} \begin{bmatrix} A & E & I & M \\ B & F & J & N \\ C & G & K & O \\ D & H & L & P \end{bmatrix}$$

The specific APAS applications are

	COMPONENT POSITION		SCALING INDIVIDUAL AXIS DIRECTIONS
$[C] =$	$\begin{bmatrix} A & E & I & 0 \\ B & F & J & 0 \\ C & G & K & 0 \\ X_o & Y_o & Z_o & 1/s^* \end{bmatrix}$	$[S] =$	$\begin{bmatrix} S_x & 0 & 0 & 0 \\ 0 & S_y & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$
	$*s =$ SCALING FACTOR		

	PERSPECTIVE VIEWING		DISPLAY POSITION
$[P] =$	$\begin{bmatrix} 1 & 0 & 0 & 1/d^* \\ 0 & 1 & 0 & 1/d^* \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$	$[D] =$	$\begin{bmatrix} A & E & I & 0 \\ B & F & J & 0 \\ C & G & K & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$
	$*d =$ VIEWING DISTANCE		

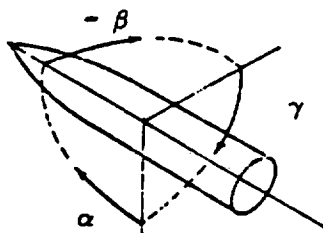
To rotate a component with position $[C]$ into viewing space $[D]$, the transformation

$$[T] = [C] \times [D]$$

will define the position in one operation. The sub matrix

$$\begin{bmatrix} A & E & I \\ B & F & J \\ C & G & K \end{bmatrix}$$

due to sideslip (β), pitch (α), and roll (γ) can be determined from a standard axis rotation and are as follows



$$\begin{aligned} A &= \cos \alpha \cos \beta \\ B &= \sin \beta \cos \gamma - \sin \alpha \cos \beta \sin \gamma \\ C &= -\sin \alpha \cos \beta \cos \gamma - \sin \beta \sin \gamma \\ E &= -\cos \alpha \sin \beta \\ F &= \sin \alpha \sin \beta \sin \gamma + \cos \beta \cos \gamma \\ G &= \sin \alpha \sin \beta \cos \gamma - \cos \beta \cos \gamma \\ I &= \sin \alpha \\ J &= \cos \alpha \sin \gamma \\ K &= \cos \alpha \cos \gamma \end{aligned}$$

APPENDIX C

OUTPUT VARIABLE DESCRIPTIONS*

INTERACTIVE

A, ALPHA	Angle of attack, α , degrees
ALT, ALTITUDE	Altitude, m or ft
B, BETA	Angle of Sideslip, β , degrees
CONFIG.	Configuration
D1,...,D6	Flap Deflection Angle, $\delta_1, \delta_2 \dots$, degrees
KS	Sand Grain Height, K_s , m or ft
M, MACH	Mach Number, M
P	Non-Dimensional Rolling Velocity, \hat{p}
PR, PRESSURE	Static Pressure, P_∞ , Nt/m ² or lb/ft ²
Q	Non-Dimensional Pitching Velocity, \hat{q}
R	Non-Dimensional Yawing Velocity, \hat{r}
T, TEMP	Static Temperature, T_∞ , °K or °R

SLENDER BODY ANALYSIS

By definition, slender body results do not vary with mach number. This can be seen in wind tunnel or flight test data. The extent such data vary is a measure of the non-slenderness of vehicle.

BC	Boundary Condition
BC	DESC
1	AL=0: $\alpha=0$ deg. (Basic Load)
2	AL=1: $\alpha=1$ deg. (Coefficient Increment Due to Unit Increment in <u>Pitch</u>)
3	QB=1: $\hat{q}=1$ rad. (Coefficient Increment Due to Unit Increment in <u>Pitching Rate</u>)
4	BE=1: $\beta=1$ deg. (Coefficient Increment Due to Unit Increment in <u>Yaw</u>)
5	PB=1: $\hat{p}=1$ rad. (Coefficient Increment Due to Unit Increment in <u>Rolling Rate</u>)
6	RB=1: $\hat{r}=1$ rad. (Coefficient Increment Due to Unit Increment in <u>Yawing Rate</u>)

*Aerodynamic symbols conform to PART I definitions

CBAR	Input Reference Chord, C_{REF}
CL	Lift Coefficient, $F_z / [qS_{REF}]$
CLL	Rolling Moment Coefficient, $M_x / [qb_{REF}S_{REF}]$
CM	Pitching Moment Coefficient, $M_y / [q C_{REF}S_{REF}]$
CN	Yawing Moment Coefficient, $M_z / [qC_{REF}S_{REF}]$
CNB1	Sectional Normal Force Coefficient, $n/[qL]$ at $\alpha = 0$
CNB2	Sectional Normal Force Slope, $d/d\alpha[n/qL]=2SPX/57.3$ [for circular bdy]
CY	Side Force Coefficient, $F_y/[qS_{REF}]$
L	Body Length (Last value in X-column of printout)
S/L**2	Normalized Body Cross-sectional Area, S/L^2 (Normalized Base Area is last value in this column, S_B/L^2)
SPAN	Input Reference Span, b_{REF}
SPX	Normalized Body Cross-sectional, $(d[S/L^2])/(d[x/L])$ Area First Derivative
SPPX	Smoothed Normalized Body Cross-sectional, Area Second Derivative $(d^2[S/L^2])/(d[x^2/L^2])$
SPPXR	Rough Normalized Body Cross-sectional, Area Second Derivative $(d^2[S/L^2])/(d[x^2/L^2])$
SREF	Input Reference Area, S_{REF}
W/L	Normalized Body Width, W/L
X	Axial Distance from Body Nose, x
X-CG	Axial Reference Point, x_{CG}
Y-CG	Lateral Reference Point, y_{CG}
Z-CG	Vertical Reference Point, z_{CG}

A useful calculation to make to check the slender body solution relative to known data is to compute the lift coefficient at $\alpha=1$. Recall that in slender body theory the value for an infinite cylinder is 2.0. The formula to use is:

$$C_{L,\alpha=1} = [S_{REF}/L^2] / [S_{BASE}/L^2] (57.3) C_{L_\alpha} = \frac{[249.91/(31.75)^2]}{.04105} (57.3) (.00792) = 2.74$$

UNIFIED DISTRIBUTED PANEL ANALYSIS

ACTIVE	Indicator to denote which components are active. (e.g. "Active" Missile in presence of "Inactive" Carrier Aircraft) 0 Inactive (Forces influence active components but are not included in force output summary) 1 Active (Only forces to appear in output)
ALPHA	Angle of Attack, α , degrees
AREA	Normal Surface Area of Quadrilateral Panel
BETA	Angle of Sideslip, β , degrees
CAVG	Average Chord, $S_{REF}/(\text{Component True Span})$
CBAR	Input Reference Chord; $\bar{c}_{\text{Delta Wing}}^{-2/3}$
CDL	Drag due to Lift, C_{D_L}
CDTHK	Total Nearfield Thickness Drag
CDTHK (BODY)	Body Nearfield Thickness Drag
CDVTX	Farfield Vortex Drag
CDO	Nearfield Drag Due to Lift, C_{D_0}
CD100	Farfield Drag Due to Lift, $C_{D_{100}}$
CHORD	Local Component Chord, C
CL	Lift Coefficient, C_L
CL*C/CAVG	Weighted Section Lift, $C_L C/C_{AVG}$
CN	Section Normal (to Surface) Force Coefficient, C_n
CN*C/CAVG	Surface Weighted Section Normal Force Coeff., $C_n C/C_{AVG}$
CN*W/L	Body Weighted Section Normal Force Coefficient, $C_n W/L$
COS(THETA)	Cosine of Quadrilateral Panel Dihedral Angle*
CP-NET	Net Pressure Across Quadrilateral Panel, $C_{P_{NET}}$
DELTA	Flap Deflection, δ , degrees

* Facing forward, positive normal is in direction of head with first chord in left hand and last chord in right hand.

D1,D2...	Flap Deflection $\delta_1, \delta_2 \dots$, deg [$\delta < 0$, LE down; $\delta > 0$, T.E.]
ETA	Nondimensional Span Station, $\eta = s/(\text{Component True Span})$
IMAGE	Quadrilateral Panel Image Indicator
INCIDENCE	Initial Component Incidence in Degrees (Same as constant Twist along Span)
LIFT	Lift Coefficient, C_L
NORMAL/SIDE	Total Force Coefficient Normal to Local Surface for Half of Component (Not Meaningful for Non-Planar Components)
P	Nondimensional Rolling Velocity, \hat{p}
PITCH	Pitching Moment Coefficient, C_m
Q	Nondimensional Pitching Velocity, \hat{q}
R	Nondimensional Yawing Velocity, \hat{r}
ROLL	Rolling Moment Coefficient, C_ℓ
SEMI-SPAN	Component Semi-Span Measured Along Surface (Total Span for Asymmetric Components)
SIDE	Side Force Coefficient, C_Y
SIN(THETA)	Sine of Quadrilateral Panel Dihedral Angle
SPANWISE PANELS	Number of Spanwise Quadrilateral Vortex/Source Panels
SUCTION	Average Level of Leading Edge Suction $(\bar{C}_{D_L} - C_{D_L})/(\bar{C}_{D_L} - C_{D_{100}})$ where $\bar{C}_{D_L} - C_{D_L}$ for $K_S = 0$
TWIST (DEG)	Local Component Twist Angle, ϵ , degrees [Calculated from $(z-le \text{ minus } z-te)/\text{chord}$]
TYPE	Component Type: 3 Vertical Surface 4 Symmetrical Surface 5 Interference Shell
W/L	Ratio of Local Body Width to Body length, W/L

X	x-coordinates for Body Stations
XBAR	x-coordinate of Quadrilateral Panel Centroid
XC	x-coordinate of Quadrilateral Panel Control point
X1	x-coordinate of Quadrilateral Panel Inboard Leading Edge
X2	x-coordinate of Quadrilateral Panel Outboard Leading Edge
X3	x-coordinate of Quadrilateral Panel Inboard Trailing Edge
X4	x-coordinate of Quadrilateral Panel Outboard Trailing Edge
X/C C.P	Nondimensional Chord Location of Section Center of Pressure
X/L	Nondimensional Coordinates for Body Stations
YAW	Yawing Moment Coefficient, C_n
YBAR	y-coordinate of Quadrilateral Panel Centroid
Y1	y-coordinate of Quadrilateral Inboard Edge
Y2	y-coordinate of Quadrilateral Outboard Edge
ZBAR	z-coordinate of Quadrilateral Panel Centroid
Z1	z-coordinate of Quadrilateral Inboard Edge
Z2	z-coordinate of Quadrilateral Outboard Edge

WAVE DRAG ANALYSIS

ALPHA	Angle of Attack, α , degrees
D/Q	Sectional Wave Drag, $d[Dw/q]/d\theta$
MACH	Mach Number, M
THETA	Cylindrical Angle, θ , degrees

SKIN FRICTION ANALYSIS

CDF SMOOTH	Hydraulically Smooth Skin Friction Drag Coefficient, C_{D_F}
------------	----------------------------------------------------------------

CDF ROUGH	Distributed Rough Skin Friction Drag Coefficient, C_{D_F}
CDF USED	Maximum of CDF Smooth and CDF Rough
KS	Sand Grain Height, K_S , m or ft
PRESS	Static Pressure, P_∞ , Nt/m^2 or lb/ft^2
REYNOLDS	Length Reynolds Number $U_\infty C/\mu_\infty$ or $U_\infty L/\mu_\infty$
TEMP	Static Temperature, T_∞ , $^\circ\text{K}$ or $^\circ\text{R}$
X/L TRANS	Component Normalized Transition Point, $x\text{-transition}/L$

APPENDIX D

DESCRIPTION OF SYSTEM SUBROUTINES

- AAMAIN - APAS II main program.
- AERO - Controls FORCE calculations.
- ANGLE (X1,Y1,X2,Y2,S)
- Evaluates angles for vector defined by (X1,Y1) and (X2,Y2) and returns the magnitude S.
- ARDC62 (ALT,PRESS,TEMP,C)
- 1962 U.S. Standard Atmosphere. Input altitude (ALT) returns static pressure (PRESS - lbs/ft²), temperature (TEMP- °R) and the speed of sound (C-ft/sec).
- AREAS - Makes cuts through a geometric component and tallys perimeter and cross-section area.
- AREAW - Makes oblique cuts through geometric components and accumulates the projected cross-section areas.
- ATMOS - Solves for the atmospheric properties using the 1962 U.S. Atmosphere.
- BDYLD - Calculates longitudinal loading on the body components.
- BLOCK - Initializes data arrays required in calculating equilibrium real gas properties of air.
- BLOCK DATA - Used to initialize the page heading array.
- BLUNT - Calculates the viscous forces on a blunt body including low density effects.
- BMTX - Calculates $[T + \beta^2]^{1/2}$ for each of the quadrilateral panels, where T is the tangent of the leading edge sweep angle and $\beta^2 = 1 - M^2$.
- BORDER (TITLE)
- Places a border around a Tektronix screen and on the underlined title (TITLE) at the top of the page.
- BOUND - Calculates the symmetric and antisymmetric boundary conditions for use with the aerodynamic influence matrices.
- CLC (N,BUF1,I1,IBUF2,I2)
- Compare N characters of BUF1 starting at character I1 against N characters in IBUF2 starting at I2.

- Curve fit routine based on a second-order weighted average technique. NI input points (XI, YI arrays) are used to fill NA points in the ANS array using the values in array T.
- COMEXT - Calculates component extents for scaling and display. Parameters used are from common/GEOM/.
- COMPON - Component management routine. APAS commands processed (ATTACH, COPY, ETC) are clearly marked. Major parameters used are from commons / COMPO/, /INDEX/, and the first 7 words of /GEOM/.
- COMPR - Calculates the local flow properties using oblique - shock relationships of NACA TR 1135.
- CONCAT (A1,A2)
 - Concatenates two words into one left adjusted word. A double precision function on the PRIME computer.
- CONE - Solves for the local properties about a cone in supersonic flow using empirically derived equations.
- CONTROL- Changes the geometry data for control surfaces to the proper deflected position.
- CONV (I1ST,BUF,I1AST)
 - Converts 1 Byte characters in BUF array to a real value starting at location I1ST through I1AST or until a delimiter (comma, space, 1, (,),) is encountered. Returns end point location in I1ST.
- CPLOT (X,Y,NP,IND,ISKIP)
 - Simple display for wave drag area cuts. Plots Y versus X for NP points. IND = 1 to scale ISKIP =0 solid line
 = 0 to use old scale >0 dashed line.
- CRVFT - Calculates a least-square error curve fit for the set of points $X_i, F_i, i = 1,n$.
- CUT (JCUT,XMP,ROT,YERO,ZERO,IDASH,LEFT)
 - Makes cuts through component indicated at the rotation indicated by ROT array and/or aircraft rotation system.

JCUT 1 Component already in position retrieve data.
 2 Position component relative to ROT angles only.
 3 Position component relative to ROT and A/C location data.

XMP Location of plane to be cut.

ROT Spacial position of plane.

YERO Origin of section in picture.
 ZERO

IDASH Dashed line indicator.

LEFT 1 Draw section to right of marker.
 2 Draw section to left of marker.

CUTSEC - Display cross-section cuts on a three-view for the component currently in common /GEOM/.

DIGIT - Digitize geometry component using the Tektronix tablet. Important variables are in commons /GEOM/, /DIGIT/, and /AXIS/. Variable IAXIS in /COMPO/ controls the drawing axis on the tablet.

DISP - Controls the type of display to be used (three-view or orthographic).

DQWS (IM,NM)
 - WAVE drag routine. Calculates total vehicle drag from S array in /COPT/. IM is current Mach number, NM is number of Mach numbers in calculation.

DRAG - Calculates untrimmed values of drag-due-to-lift for three angles of attack. These values are used to determine the coefficients in a parabolic drag polar equation.

EDIT - Executive routine for edit function. Controls calls to subroutines in the edit family and adjustments to parametric component data. Major variables are found in /GEOM/, /PANL/, /COMP/, /ED/, and /EDD/.

EDITN - Screen edit routine uses a pictorial of a component and the cross-hairs to make changes to the component's geometry. Major parameters are from /GEOM/, /COMPO/, /INDEX/, /ED/, and /EDD/.

EDPUT - Edit command interpreter. Converts alphanumeric terminal input into numerics in common/EDD/.

ELPI - Approximates elliptic integrals of the first and second kind.

EMLORD (IT,DA)
 - Cross-section interpolation routine to enhance data supplied in the TERMINAL function. Uses an EMINTION LORD curve fit method. Variable IT is the type of body component, and the output is stored in the array DA.

EQUA - Calculates the parabolic drag due to lift equations from three data points.

EXPAND - Calculates local flow conditions using Prandtl-Meyer relationships of NACA TR 1135.

FILL - Fills intermediate locations in an array using cosine axial spacing.

FINDW (ICOL,ILAST,CCOL,VALUE,IFLG)
 - Searches a single character buffer, "CCOL" and returns the first word encountered as a packed word "FINDW" double precision function on 32 bit machines.

"ICOL" is the first position within CCOL to be searched, or return, ICOL - the position of the delimiter encountered immediately after the returned word.

"ILAST" is the last position within CCOL to be searched, returned unaltered.

"Value" is returned as the value of a number which follows the returned word immediately or one delimiter past.

If the word begins with a "C" it is assumed to be a data coefficient, such as "CL". If the coefficient is "CL", "CM", "CY", ~CN", or "CR" any additional characters following are assumed to be a slope subscript. In the case of "CLA" the first part "CL" would be returned in "FINDW" and the variable name "A" would be returned in "VALUE".

on return, IFLG=0 If a word is encountered and is followed by another.
IFLG=99 If a double blank follows the returned word.
IFLG=100 If no word is encountered within the field.
IFLG=99 If a number returned in "VALUE" was preceded by a "(".

FIT (N X,Y,NN,XX,YY,IOR,R,ITY)

- Interpolates broken line using spline fit or least squares smoothing up to tenth order.

N No. of input points, N>3.
X,Y Input point arrays.
NN No. output points.
XX,YY Output point arrays, XX must be specified.
IOR Maximum desired least squares order.
R Initial radius of curvature of curve.
-R, radius is calculated, least squares only.
ITY 1- Least Squares; 2-CODIM fit; 3- Linear fit.

FITWT (MUM,XX,XX,MM,XP,YP,R,N)

This subroutine fits a curve

$Y = \text{SORT}(2.*R*X) + A(L)*X + A(2)*X**2 + \dots + A(N)*X**N$

through the points X(I)) such that

1. The curve goes through (0,0) and (X(M),Y(M)).
2. The initial radius of curvature is equal to R.
3. The error (Y-Y(I)) is a minimum in the least square sense.
4. If (ABS(Y(2)-Y(1)).LT>R point is eliminated.

MUM is the number of points (X(I),Y(I)).
MM is the number of output points.
N is the order of the polynomial.
M must be greater than or equal to N.

All X(I) must be greater than 0.

YY,A1,A2,A3, are scratch arrays of dimension M.

The solution is $A(I) = A(I,1,\dots,N)$.

FIT3 (NN,X,Y,Z,NC,NS,XP,YP,ZP)
 - Three-dimensional linear curve fit. Input arrays XP and ZP are two-dimensional. NC,X,NS, YP is dimensioned NA with one value of YP for each NC values of XP and ZP. The value of Z is interpolated for each value of X and Y for NN output points.

FLOSEP - Determines the effect of flow separation caused by the deflection of a control surface at hypersonic speeds.

FORCE - Determines the pressure coefficients on each quadrilateral element, resolves the force in the required body axis system, and sums the contributions of each element to give hypersonic six component characteristics.

GENTB - Hypersonic paneling routine for body components. Unwetted areas on bodies are bypassed. /GEOM/ and /GENT/ common blocks are used.

GENTS - Hypersonic paneling routine for surfaces. Uses /GEOM/ and /PANL/ to break out leading edge, flaps, and surfaces. Also uses common /GENT/.

GEOEX - Main executive command interpreter. Inputs an alphanumeric string from the terminal and converts it to numeric code variables in common /COMPO/.

GETRUN (JCONF)
 - Interrogates local file and determines if a new or old configuration is stored. Inputs configuration parameters, SREF, CBAR, SPAN, XCG, YCG, ZCG for a new configuration. Uses common /OINDEX/ and /INDEX/.

GREEK (I)
 - Draws Greek symbols λ , Λ , and γ at current Tektronix screen location for I = 1,2, or 3, respectively.

GRID - Subroutine to produce a grid in subroutine PLOTIT. Inputs select scaling factors, grid type, axis orientation and zero point location.

HEADER - Provides a title at the top of each page of the output and advances the page counter.

HSHLDR - Function to solve systems of simultaneous equations using the Householder method. Non-square solution sets are solved least square.

IDATA - Inputs viscous drag calculation conditions. Commons /GEOM/, /COPTV/, /PLOTV/, and /CDAT/ are used.

INFO - Inputs and interprets basic surface definition parameters, SW, AR, λ , Γ . Will also draw a box in the upper right-hand corner of the screen if requested.

INTE - Subroutine for constructing interference shells. Uses a three-view and the graphics cursor to define the surface. Uses commons /GEOM/, /PANL/, and /INDEX/.

INTEG - Integrates net pressures to establish section and total loads for each component.

INTSCT - Calculates the intersection (X,Y) of two lines determined by connecting (X1,Y1), (X2,Y2) and (X3,Y3), (X4,Y4).

INTSCT=0 Solution for (X,Y) completed.

INTSCT=1 Parallel lines, no solution.

INTSCT=1 The lines coincide.

INVEST (NC,FILE,NCR,ITYPE)

- Investigates ICOM array against the index array for requested files and returns the record number for each local component.

NC Number of components on input list.

FILE Unit number to be investigated.

NCR Number of components being returned.

ITYPE 1 : normal find.

 2 : find all components - and +.

 3 : search for - components and place record number in ICOM array.

ISIMEQ - Solves a system of linear equations by Gaussian elimination.

ISTRING (I1ST,ILAST,BUF,NTOT,VALUE)

- Routine to convert a string of numbers, separated by commas or blanks, within buffer "BUF", beginning at character "I1ST" and ending when any delimiter or a double blank is encountered.

"ILAST" is the last character within BUF to be searched.

The array of integer converted values is returned within "VALUE".

"I1ST" is returned as the position of the next delimiter following the converted string or as the position immediately following a ")" at the end of the numeric string.

LIMIT (IC)

- Calculates component (IC) limits for viscous drag section cuts. Input data from /GEOM/. Output stored in /CLIM/.

LINEAR (X1,Y1,N1,X0,Y0,NO)

- Linear curve fitting routine. Input array X1,Y1 of size N1 are used to interpolate NO values of Y0 at points in X0.

LIST - Terminal input edit function. Keyboard command interpreted by EDPUT are carried out in LIST. Section inserting, deleting, duplicating, point translation with graphics cursor, and listing cross-section displays. Section translation, scaling, and component scaling are also performed in LIST. Commons /GEOM/, /EDD, /ED/ contain most of the important variables.

LSEE - Interprets surface geometry in /GEOM/ for subsonic-supersonic paneling. Resulting data is displayed for model verification.

MAIN - Hypersonic analysis control program.

MATMUL (M,NX,N,A,B,C,ITRANS)
 - Performs matrix multiplication $A(M,NX) * B(NX,N) = C(M,N)$.
 A, B, C size is given in the dimension statement.

MATR (F,ANG)
 - Fills in 4 x 4 rotation matrix F based on yaw, pitch, and roll angles stored in ANG.

MATRIX - Compute coefficients for slender body wave drag equation in subroutine EMLORD.
 - calculates the aerodynamic influence matrices for both source (thickness) and vortex (lift) panels.

MAXIT (B,Y,NYS,YMIN,YMAX,YMID,DIV)
 - Given NYS values of X, MAXIT calculates the extents (YMIN,YMAX), the midpoint ,YMID, and plot spacing ,B, based on DIV grid spaces.

MENU - Menu of key functions in VIEW subcommand in EDIT. Displayed on screen.

MENUI - Menu of key functions in the INTERFERENCE command in EDIT. Displayed on screen.

MENUP - Menu of key functions in the PANEL subcommand in EDIT. Displayed on screen.

MSOL - Subroutine MSOL uses the method of Householder to solve the linear set of aerodynamic influence equations.

MULTIP - Rings Tektronix bell for indicating errors in users input.

MULVEC (X1,Y1,Z1,H1,F,X,Y,Z,H)
 - Subroutine MULVEC multiplies the vector (X,Y,Z,H) by transformation matrix F with resulting vector of (X1,Y1, Z1,H1)

NEWTPM - Newtonian + Prandtl-Meyer blunt-body method.

NORMAL - Calculates normal wash in the Trefftz plane at each span station for farfield vortex drag.

SO Grid increment for vertical axis.
0.0 arbitrary scaling.

XS (+1.0) standard plot horizontal.
(-1.0) reverse grid.

YS (+1.0) standard plot vertical.
(-1.0) reverse grid.

TITLE 80 character title for plot.

PLOT0 - Displays analysis data which is stored in the output file.
Alphanumeric input from the keyboard is interpreted and displays of
the data requested are drawn on the screen. Uses commons /OINDEX/,
and /CHAR/.

PLOTOT - Displays an outline of a surface component with or without
sections. TYPE 4 surfaces are drawn in the X-Y plane, TYPE 3 in
three-view and TYPE 5 components are unwrapped. Commons /GEOM/,
/ED/, and /EDD/ are used.

PLTLNE (NPTS,X,Y,TOL,IDASH)
- Display a line X-Y (of NPTS points) using only points required to
meet tolerance (TOL(degrees)). IDASH=0=solid
IDASH>0=dashed line.

PLTONE - Displays component in /GEOM/ in stick-figure form with orientation
matrix AMAT.

POLY - Generates an N-th order polynomial.

PRESS - Calculates and stores the axial perturbation velocities and net
pressures for each of the unit solutions on the plot output file.
PRESS also calculates the perturbation velocities at field points.

PRINT - Used to print the source and vortex aerodynamic influence matrices,
PRINT is called from the MAIN program and is normally a comment
statement. If a print of the aero matrices is required for a
specific case, the c must be removed from column 1 of the call
statement, the MAIN program must be recompiled and the UDP program
relinked.

PUNCH - Writes element data card images on tape 8.

QC - Determines the aerodynamic heating at the given wall temperature.

QINT - Calculates a quadratic interpolation with given values.

RADIUS - Calculate leading-edge radius using a polynomial fit.
 Within this code is a check on x/c spacing.
 If $\Delta(x/c) \leq 0.00025$, the code assumes that the user is setting the L.E. radius with points on the circumference of a cylinder. This feature is useful when one includes L.E. vortex effects in the calculation and it is important to exactly control the L.E. radius. The L.E. is assumed to be at $x/c = 0.0$. If the next x/c is at 0.00025 or less the program will assume the z/c's provided at these x/c's lie on the surface of a cylinder. Only the upper surface need be supplied (z/c data on cylinder).

READN (KEY,IIN,IOUT,VALUE)
 - Reads in number in free-format from KEY and loads them into VALUE array. IIN is the number of values to read in. IIN=0 for variable number, IOUT is the number of values actually returned. Alphanumeric inputs are interpreted as zero's.

REALOT (ABC)
 - Displays number ABC using Tektronix routine AOUTST and a F12.3 format.

REANUM (N,NMAX,INP,ILIM)
 - Interprets a numerical value in alphanumeric array INP starting at location N and proceeding to NMAX or the first delimiter. The type of delimiter encountered is returned in ILIM.

REVERS - Reverses the storage order of the symmetric and antisymmetric boundary conditions and solutions.

ROMU - Calculates various equilibrium real gas properties for air.

RUNOUT - Calculates the linearized forces and moments, including wave drag and skin friction drag, for each of the wind tunnel run conditions. Where applicable, nonlinear force and moment increments due to leading-edge and side-edge vortex formation are included.

SAVEB - Digitizer curve-fit routine. Organizes data accumulated from DIGIT on scratch file. Determines number of points per segment and cross-sections. Curve fits and/or smooths digitized data for each cross-section. Some keyboard input required for max point determination and smoothing algorithms.

SCALE (ISCALE,AMAT,FILL,XM,XL,XR,YB,YT)
 - Scales component(s) into a screen space for the orientation given by AMAT.

ISCALE -
 1 SCALE bounds of initial component.
 2 SCALE bounds of additional component.
 3 SCALE present bounds into viewing space.
 4 Finish initial SCALE and bound into viewing space.
 5 Finish add SCALE and bound into viewing space.

AMAT Matrix of viewing space for ISCALE = 2.

FILL Percentage of screen to fill with image.

XM Array of computed boundaries.

XL Left boundary.

XR Right boundary.

YB Bottom boundary.

YT Top boundary.

SCALIT (YMAX, SCALE, IS, YMID, IC, IXID)

- Sets grid scaling factor (SCALE) based on approximate spacing (YMAX), selects format statement to be used to display the grid (IS), and determine parameters for locating the center grid line (IC, IXID) using the midpoint (YMID).

SDATA - Prepares geometry data for use by the rest of the program.

SDQ (DQWT, DQWN)

- Calculates the area under curve (DQWT) then divides it by the length to get roll angle wave drag (DQWN). Commons /CFIXW/ and /CTHE/ provide integer and length values.

SECT (IND, VAL, ND, X, Y, Z, NPH, NH, ITYPE)

- Section insert/delete.

IND = 1 CODIM interpolation.
IND = 2 LINEAR interpolation.
IND = 3 Delete section ND.

VAL interpolation point.

X, Y, Z geometry point arrays.

NPH number of points/cross-section.

NH number of cross-sections.

ITYPE type of component.

SEEGEN (NCOMP, XM)

- Hypersonic geometry display using limit parameters from GENTS and GENTB (XM array). NCOMP components are read off a scratch file and displayed on screen at angles of yaw, pitch, and roll. Similar to ORTH.

SENDC (IR,IT)
 - Transmits geometry in file record IR and the panel geometry if a surface component in record IT in card image form. Data is placed on the file designed to transfer data in a distributed net work.

SENDER (IUNIT,N,ARRAY)
 - Writes N values of array ARRAY onto unit IUNIT using a 6E12.5 format.

SET - Analysis set-up routine. Alphanumeric input from the keyboard is interpreted by SET and placed in specific data locations on the analysis output (PLOT) file. Missing data is requested by the routine. The last section of SET sorts out required analysis runs and geometry and places them into the card image data transmission file. Commons /OINDEX/ and /CONDTN/ contain the primary variables used here.

SETGEM - Reviews the run index in the PLOT file prepared in SET and selects configuration and analysis models required for review prior to sending the data for analysis. Commons used /GEOM/, /PANL/, /OINDEX/, and /CONDTN. Initial conditions of /GENT/ are filled in here.

SETHYP - Interrogative routine used to fill in hypersonic analysis methods. Default methods and values are built into the routine. Fills in DEFINE array in /GEOM/.

SHIFT (KC,ITYPE,SY,SZ)
 - Re-arranges KC points in SY, SZ arrays based on point type (ITYPE array). Scheme is for AREAS and AREAW routines to assure points from section cuts are integrated in the proper order.

SHKEXP - Performs a streamwise shock expansion analysis.

SKINF - Skin friction calculation. Uses general geometric quantities stores in common /CDAT/ to calculate viscous drag at various input atmospheric or wind-tunnel conditions.

SLEN - Slender body generation. Combines from one to six body subcomponents into a single slender body with allowance for overlapping. Common /GEOM/ contains all the input and output data.

SMOTHL (NN,X,DYDX,BC,IORDER)
 - A piecewise least squares smoothing routine which takes input points (X,BC), and smooths BC and determines the first derivative at each point in X. The resultant values are output in arrays Y and DYDX respectively.

SOLVE - Controls the solution of the symmetric and antisymmetric aerodynamic influence equations.

SORTER (N,X,Y)
 - Sorts N values of X and Y into ascending order based on X.

SOURCE - Calculates the influence of a constant or linearly varying source panel on a control point.

SPCTOL (TOL,WF,N,Y,Z,S,NPS,SS,XIN,XEND,DR,XN,SP)

- Spaces points along the independent axis of a three-dimensional curve based on the relative angular change.

TOL Spacing increment (in degrees).

WF Weighting factor for spacing (0.0 - 1.0).

N Number of points input.

NPS Number of points output.

 < 0 - Calculate NPS only.
 = 0 - Calculate NPS and SS array.
 > 0 - Use old NPS and calculate SS array.

Y First coordinate array.

Z Second coordinate array.

S $S(I) = X(I)$
 $S(I) = \text{SUM}(I-1,N) \text{ SQRT}(Y(I)-Y_0)^2 + (Z(I)-Z_0)^2$

SS Spaced values of S, SS(1)=0.0, SS(NPS)=1.0

DR,XN,SP Scratch arrays same size as SS array.

STRING (I1ST,I1AST,BUF,NTOT,VALUE)

- Routine to convert a string of numbers, separated by comas or blanks, within buffer "BUF", beginning at character "LIST" and ending when any delimiter or a double blank is encountered.

"I1AST" is the last character within BUF to be searched.

The array of real converted values is returned within "VALUE".

"I1AST" is returned as the position of the next delimiter following the converted string or as the position immediately following a ")" at the end of the numeric string.

SYMLEG (MLEFT,MTOP,NCURV,RUNS,LABLE,VALUES,ORDFIX,NPD,ETAV)

- Routine to draw a symbol legend of the form:

(MTOP)

SYMBOL	RUN	"LABEL"	ETA
	"RUNS(1)"	"VALUES(1)"	"ETAV(1)"
	"RUNS(2)"	"VALUES(2)"	(CPPLOTS
	.	.	ONLY"
	.	.	
	"RUNS(INCURV)"	"VALUES(INCURV)"	

(MLEFT) "MTOP" and "MLEFT" are Tektronix absolute coordinates

"SYMBOL" column is left off if "NCURV" is negative

ORDFIX is the ordinate plot parameter type for CP plots. ORDFIX=23 when both upper and lower surface pressures are plotted. In this case, upper is plotted with solid lines and lower is plotted with dashed lines and the same symbols. A line legend is plotted in this routine.

NPD is an array of symbols used for each label type.

SYMM(I,M,N,K)

- Symbol plotting routine. Plots symbol (I) of size (K) at screen location (M,N).

SYM(IX<IY)

- Plots a triangle at screen location (IX,IY).

SYMV(X,Y)

- Plots a triangle at virtual screen location (X,Y).

TEMP - Iterative procedure to calculate the surface equilibrium temperature for either an ideal or a real gas.

TERMIN - Simple keyboard inputs to create surface and body components. Common/GEOM/ and array DA are used.

THINER (IP,XG,YG,ZG,IT,TOL,SS,ST,XP,YP,ZP,SP,ISCR)

- Reduces arrays XG, YG, ZG using YG and ZG as reference arrays. The value of TOL determines the tolerance of the spacing. IP is the number of points (in and out), IT is the number of points per section, ISCR is SCRATCH file unit number. All other arrays are SCRATCH arrays.

TLU (XI,YI,ZI,NI,XO,YO,ZO,NO)

- Linear interpolation of YI and ZI based on XO. NI input points from arrays XI, YI, ZI are used to evaluate NO output points in XO, YO, ZO arrays.

TRAP - Keyboard definition of a simple trapezoidal surface. Inputs of SW, AR, λ , Γ , t/c's and wing section type are used.

TTABLE - Performs the interpolation to find the thickness correction factors.

UTILIT - Keyboard input routine for changing system file management, title and units default parameters.

VALUE - Subroutine VALUE calculates the value of the integral $\int_0^1 f(x) dx$
where $f(x) = a_1 x(1-x) + a_2 x^2(1-x)$.

VECTOR - Converts input thrust vector data to coefficients and adds the results to the vehicle aerodynamic coefficients.

VIEWER (ISENSE, PX, PY, PZ, NPT, IDASH)
- Checks a panel defined by PX, PY, and PZ arrays to see if the normal vector is facing away or towards the screen. ISENSE indicates if the panel is a clockwise or counterclockwise formation. NPT is the number of points to display. IDASH = 0 solid, IDASH >0 dashed display.

VIEW3 - Three-view display. Geometry components listed in /COMPO/ are input into /GEOM/ and displayed on the screen.

VISC - Viscous drag calculation control. Checks local file for a configuration then controls input and calculations.

VORTEX - Calculates the influence of a constant pressure panel on a control point.

VTX - Calculates farfield vortex drag for three angles of attack.

WAVE - Wave drag calculation control. Checks local file for a configuration, then controls input and calculations.

WET (IX, XSURF)
- Updates perimeter and area arrays in /CXXXV/ to reflect new section cuts.

WSVP - Calculates and displays total surface area and volume.

XACALW - Global scaling for wave drag. Uses component parameters in /GEOM/ to fill in arrays in /CLIMW/.

XYZ (DA, L)
- Card image data stored in DA is converted into surface and body components and stored in /GEOM/.

XYZR - Geometry preparation for wave drag. Takes input geometry in /GEOM/, adapts it for wave drag and stores its output in /CXXXW/.

APPENDIX E

ALTERNATE PROGRAM USAGE

Square 8 of figure 2-2 provides a list of alternate program link-ups with the APAS. Examples of job control language (JCL) and required inputs are provided for the APASOUT, APASIN, PATRANG and MBYU interfaces.

APASOUT

Function

Convert an APAS binary geometry file [permanent or component] to card image. Used to ship data between users at different locations or for providing interface data with other programs.

Job Control Language (For PRIME Machines, release 20.02 or earlier)

The following JCL is used to create an executable load module from the interface source code stored in OCT86.APASOUT.F77 and OCT86.APAS.UTILITIES.

```
COMO APASOUT.CREATE.BIND.COMO
DATE
F77 OCT86.APASOUT -BIG -SILENT -BIN OCT86.APASOUT.BIN -SAVE
BIND
LO OCT86.APASOUT
LO OCT86.APAS.UTILITIES
LI
MAP -UNDEFINED
MAP OCT86.APASOUT.MAP -FULL
FILE OCT86.APASOUT
DELETE OCT86.APASOUT.MAP
DELETE OCT86.APASOUT.BIN
DELETE APASOUT.CREATE.BIND.COMO
COMO -E
```

Usage on PRIME Machines

→→→ RUN OCT86.APASOUT.RUN

INPUT THE COMPLETE NAME FOR PERMANENT GEOMETRY DATA DIRECT ACCESS FILE.

→→→ SHUTTLE.GEOM [a binary geometry file]

IF FILE STATUS OF ** (OLD) ** IS CORRECT - HIT RETURN - IF NOT ENTER NO

→→→ <CR>

```
** OPEN FILE 1 FOR PERMANENT GEOMETRY DATA DIRECT ACCESS FILE    OLD **
** ENTER FILE NAME FOR CARD IMAGE DATA SET TO BE CONSTRUCTED    NEW **
```

→→→ APASOUT.GEOM

IF FILE STATUS OF ** (NEW) ** IS CORRECT, HIT RETURN - IF NOT ENTER NO

→→→ <CR>

```
** OPEN FILE 14 FOR CARD IMAGE DATA SET TO BE CONSTRUCTED        NEW **
```

[The direct access record numbers versus component numbers as found in the SHUTTLE.GEOM file are printed to the screen as follows:]

[Negative component numbers occur only if the component has been paneled.]

RECORD	2	100.00	1NOSE CONE	RECORD	34	350.00	4ASYM/WING W/ELEV
RECORD	3	101.00	1FOREBODY	RECORD	35	-350.00	4ASYM/WING W/ELEV
RECORD	4	102.00	1COCKPIT	RECORD	36	351.00	4ASYM/WING W/AIRE
RECORD	5	103.00	1AFT COCKPIT	RECORD	37	-351.00	4ASYM/WING W/AIRE
RECORD	6	104.00	1CARGO BAY	RECORD	38	370.00	4ASYM/WING W/ELEV
RECORD	7	105.00	1AFT FUSE+OMS 1+2	RECORD	39	-370.00	4ASYM/WING W/ELEV
RECORD	8	300.00	3VERTICAL TAIL	RECORD	40	371.00	4ASYM/WING W/AIRE
RECORD	9	-300.00	3VERTICAL TAIL	RECORD	41	-371.00	4ASYM/WING W/AIRE
RECORD	10	106.00	1AFT FUSE+OMS 3+4	RECORD	42	223.00	3TIP FINS
RECORD	11	107.00	1FUSE + OMS BASE	RECORD	43	-223.00	3TIP FINS
RECORD	12	108.00	1BODY FLAP STUB	RECORD	44	701.00	4ASYM/WING LHS
RECORD	13	109.00	1BODY FLAP	RECORD	45	-701.00	4ASYM/WING LHS
RECORD	14	302.00	3VERTICAL TAIL	RECORD	46	721.00	4ASYM/WING RHS
RECORD	15	-302.00	3VERTICAL TAIL	RECORD	47	-721.00	4ASYM/WING RHS
RECORD	16	301.00	3VERTICAL TAIL	RECORD	48	731.00	3ASYM/TIP FIN RHS
RECORD	17	-301.00	3VERTICAL TAIL	RECORD	49	-731.00	3ASYM/TIP FIN RHS
RECORD	18	400.00	3VERTICAL TAIL	RECORD	50	711.00	3ASYM/TIP FIN LHS
RECORD	29	-400.00	3VERTICAL TAIL	RECORD	51	-711.00	3ASYM/TIP FIN LHS
RECORD	19	500.00	120 H/A CONE T-15	RECORD	52	901.00	3VERTICAL TAIL
RECORD	20	200.00	4WING W/ELEVON	RECORD	53	-901.00	3VERTICAL TAIL
RECORD	21	-200.00	4WING W/ELEVON	RECORD	54	900.00	3VERTICAL TAIL
RECORD	22	201.00	4WING W/AILERON	RECORD	55	-900.00	3VERTICAL TAIL
RECORD	23	-201.00	4WING W/AILERON	RECORD	56	902.00	3VERTICAL TAIL
RECORD	24	600.00	7SLEN BODY	RECORD	57	-902.00	3VERTICAL TAIL
RECORD	25	601.00	5INTERF SHELL	RECORD	58	950.00	4WING W/ELEVON
RECORD	26	-601.00	5INTERF SHELL	RECORD	59	-950.00	4WING W/ELEVON
RECORD	27	401.00	3VERTICAL TAIL	RECORD	60	960.00	4WING FLAPLIN
RECORD	28	-401.00	3VERTICAL TAIL	RECORD	61	-960.00	4WING FLAPLIN
RECORD	30	402.00	3VERTICAL TAIL	RECORD	62	970.00	4WING CON XC
RECORD	31	-402.00	3VERTICAL TAIL	RECORD	63	-970.00	4WING CON XC
RECORD	32	401.50	3VERTICAL TAIL	DATA FOR ANALYSIS SUCCESSFULLY			
RECORD	33	-401.50	3VERTICAL TAIL	STORED IN TRANSMIT FILE			

APASIN

Function

Convert an APASOUT card image data set to a binary geometry file [permanent or component] which can be used directly in APAS.

Job Control Language (For PRIME Machines, release 20.02 or earlier)

The following JCL is used to create an executable load module from the interface source code stored in OCT86.APASIN.F77 and OCT86.APAS.UTILITIES.

```
COMO APASIN.CREATE.BIND.COMO
DATE
F77 OCT86.APASIN -BIG -SILENT -BIN OCT86.APASIN.BIN -SAVE
BIND
LO OCT86.APASIN
LO OCT86.APAS.UTILITIES
LI
MAP -UNDEFINED
MAP OCT86.APASIN.MAP -FULL
FILE OCT86.APASIN
DELETE OCT86.APASIN.MAP
DELETE OCT86.APASIN.BIN
DELETE APASIN.CREATE.BIND.COMO
COMO -E
```

Usage on PRIME Machines

→→→ RUN OCT86.APASIN.RUN

INPUT THE COMPLETE NAME FOR PERMANENT GEOMETRY DATA DIRECT ACCESS FILE.

→→→ NEWFILE.GEOM [Enter name of new binary geometry file in which to store]
[APASOUT.DATA card image file]

IF FILE STATUS OF ** (NEW) ** IS CORRECT - HIT RETURN - IF NOT ENTER NO

→→→ <CR>

```
** OPEN FILE 1 FOR PERMANENT GEOMETRY DATA DIRECT ACCESS FILE    NEW **
** ENTER FILE NAME FOR EXISTING CARD IMAGE DATA SET                OLD **
```

→→→ APASOUT.GEOM

IF FILE STATUS OF ** (OLD) ** IS CORRECT, HIT RETURN - IF NOT ENTER NO

--→ <CR>

```
** OPEN FILE 5 FOR EXISTING CARD IMAGE DATA SET                    NEW **
```

[The direct access record numbers versus component numbers as found in the APASOUT.GEOM file are printed to the screen as follows:]

[Negative component numbers occur only if the component has been paneled.]

RECORD	2	100.00	1NOSE CONE	RECORD	34	350.00	4ASYM/WING W/ELEV
RECORD	3	101.00	1FOREBODY	RECORD	35	-350.00	4ASYM/WING W/ELEV
RECORD	4	102.00	1COCKPIT	RECORD	36	351.00	4ASYM/WING W/AIRE
RECORD	5	103.00	1AFT COCKPIT	RECORD	37	-351.00	4ASYM/WING W/AIRE
RECORD	6	104.00	1CARGO BAY	RECORD	38	370.00	4ASYM/WING W/ELEV
RECORD	7	105.00	1AFT FUSE+OMS 1+2	RECORD	39	-370.00	4ASYM/WING W/ELEV
RECORD	8	300.00	3VERTICAL TAIL	RECORD	40	371.00	4ASYM/WING W/AIRE
RECORD	9	-300.00	3VERTICAL TAIL	RECORD	41	-371.00	4ASYM/WING W/AIRE
RECORD	10	106.00	1AFT FUSE+OMS 3+4	RECORD	42	223.00	3TIP FINS
RECORD	11	107.00	1FUSE + OMS BASE	RECORD	43	-223.00	3TIP FINS
RECORD	12	108.00	1BODY FLAP STUB	RECORD	44	701.00	4ASYM/WING LHS
RECORD	13	109.00	1BODY FLAP	RECORD	45	-701.00	4ASYM/WING LHS
RECORD	14	302.00	3VERTICAL TAIL	RECORD	46	721.00	4ASYM/WING RHS
RECORD	15	-302.00	3VERTICAL TAIL	RECORD	47	-721.00	4ASYM/WING RHS
RECORD	16	301.00	3VERTICAL TAIL	RECORD	48	731.00	3ASYM/TIP FIN RHS
RECORD	17	-301.00	3VERTICAL TAIL	RECORD	49	-731.00	3ASYM/TIP FIN RHS
RECORD	18	400.00	3VERTICAL TAIL	RECORD	50	711.00	3ASYM/TIP FIN LHS
RECORD	29	-400.00	3VERTICAL TAIL	RECORD	51	-711.00	3ASYM/TIP FIN LHS
RECORD	19	500.00	120 H/A CONE T=15	RECORD	52	901.00	3VERTICAL TAIL
RECORD	20	200.00	4WING W/ELEVON	RECORD	53	-901.00	3VERTICAL TAIL
RECORD	21	-200.00	4WING W/ELEVON	RECORD	54	900.00	3VERTICAL TAIL
RECORD	22	201.00	4WING W/AILERON	RECORD	55	-900.00	3VERTICAL TAIL
RECORD	23	-201.00	4WING W/AILERON	RECORD	56	902.00	3VERTICAL TAIL
RECORD	24	600.00	7SLEN BODY	RECORD	57	-902.00	3VERTICAL TAIL
RECORD	25	601.00	5INTERF SHELL	RECORD	58	950.00	4WING W/ELEVON
RECORD	26	-601.00	5INTERF SHELL	RECORD	59	-950.00	4WING W/ELEVON
RECORD	27	401.00	3VERTICAL TAIL	RECORD	60	960.00	4WING FLAPLIN
RECORD	28	-401.00	3VERTICAL TAIL	RECORD	61	-960.00	4WING FLAPLIN
RECORD	30	402.00	3VERTICAL TAIL	RECORD	62	970.00	4WING CON XC
RECORD	31	-402.00	3VERTICAL TAIL	RECORD	63	-970.00	4WING CON XC
RECORD	32	401.50	3VERTICAL TAIL				GEOMETRY DATA SUCCESSFULLY STORED
RECORD	33	-401.50	3VERTICAL TAIL				

PATRANG

Function

Create data sets that can be used directly in either COLOR or PATRAN-G software. Helpful in pre- and post-processing of APAS data, allowing the user to obtain shaded model views, isobars, isotherms, etc. in three-dimensional views.

Job Control Language (For PRIME Machines, release 20.02 or earlier)

The following JCL is used to create an executable load module from the interface source code stored in OCT86.PATRANG.F77 and OCT86.APAS.UTILITIES.

```
COMO PATRANG.CREATE.BIND.COMO
DATE
F77 OCT86.PATRANG -BIG -SILENT -BIN OCT86.PATRANG.BIN -SAVE
BIND
LO OCT86.PATRANG
LO OCT86.APAS.UTILITIES
LI
MAP -UNDEFINED
MAP OCT86.PATRANG.MAP -FULL
FILE OCT86.PATRANG
DELETE OCT86.PATRANG.MAP
DELETE OCT86.PATRANG.BIN
DELETE PATRANG.CREATE.BIND.COMO
COMO -E
```

Usage on PRIME Machines

→→→ RUN OCT86.PATRANG.RUN

ENTER DSN FOR PLOTDSN.PATRANG.DATA. DSN TAKEN FROM HABP ANALYSIS RUN

→→→ T\$HABP09 [Results data for temp, pressure, heating rate, etc]

IF FILE STATUS OF **(OLD)** IS CORRECT - HIT RETURN - IF NOT ENTER NO

→→→ <CR>

```
** OPEN FILE 12 FOR PLOTDSN.PATRANG.DATA          FILE IS      OLD **
** ENTER DSN FOR PLOTDSN.MKIII.DATA.  DSN TAKEN FROM HABP RUN
```

→→→ T\$HABP05 [Geometry data]

IF FILE STATUS OF **(OLD)** IS CORRECT, HIT RETURN - IF NOT ENTER NO

→→→ <CR>

```
** OPEN FILE 5 FOR PLOTDSN.MKIII.DATA          FILE IS      OLD **
** ENTER DSN FOR PATRAN-G NULLFILE (FORMATTED) OUTPUT
```

→→→ PAT.NULL

IF FILE STATUS OF ** (NEW) ** IS CORRECT, HIT RETURN - IF NOT ENTER NO

→→→ <CR>

** OPEN FILE 7 FOR DSN FOR PATRAN-G NULLFILE (FORMATTED) OUTPUT NEW **
** OPEN FILE 8 FOR NULLFILE SCRATCH DATA SET SCR **
** ENTER DSN FOR PATRAN-G RESULTS (FORMATTED) OUTPUT

→→→ PAT.RES

IF FILE STATUS OF ** (NEW) ** IS CORRECT, HIT RETURN - IF NOT ENTER NO

--→ <CR>

** OPEN FILE 10 FOR DSN FOR PATRAN-G RESULTS (FORMATTED) OUTPUT NEW **

1

PROCESSING # 1 WITH IXX,IS,ITYPE,NEH,L,LL= 9 4 1 9 0 0

PROCESSING # 2 WITH IXX,IS,ITYPE,NEH,L,LL= 10, 4 1 10 36 36

"

"

"

PROCESSING # 31 WITH IXX,IS,ITYPE,NEH,L,LL= 10, 1 -3 24 1146 1156

FOLLOWING DATA VAUES ENCOUNTERED - PLEASE SELECT AN I

I	ALPHA	BETA
---	-------	------

1	0.00	0.00
---	------	------

2	10.00	0.00
---	-------	------

→→→ 2

YOU WILL HAVE A RESULTS FILE CREATED FOR

APHA,BETA= 10.00 0.0

*****STOP

MBYU

Function

Create data sets that can be used directly in Movie Brigham Young University software⁶ to create shaded (or color) model views in three-dimensions. Also creates a Part/Polygon summary table that can be helpful in selecting colors for portions of the model for MBYU display.

Job Control Language (For PRIME Machines, release 20.02 or earlier)

The following JCL is used to create an executable load module from the interface source code stored in OCT86.MBYU.F77 and OCT86.APAS.UTILITIES.

```
COMO MBYU.CREATE.BIND.COMO
DATE
F77 OCT86.MBYU -BIG -SILENT -BIN OCT86.MBYU.BIN -SAVE
BIND
LO OCT86.MBYU
LO OCT86.APAS.UTILITIES
LI
MAP -UNDEFINED
MAP OCT86.MBYU.MAP -FULL
FILE OCT86.MBYU
DELETE OCT86.MBYU.MAP
DELETE OCT86.MBYU.BIN
DELETE MBYU.CREATE.BIND.COMO
COMO -E
```

Usage on PRIME Machines

→→→ RUN OCT86.MBYU.RUN

ENTER DSN FOR PLOTDSN.PATRANG.DATA. DSN TAKEN FROM HABP ANALYSIS RUN

→→→ T\$HABP09 [Results data for temp, pressure, heating rate,etc. - not used]

IF FILE STATUS OF ** (OLD) ** IS CORRECT - HIT RETURN - IF NOT ENTER NO

→→→ <CR>

** OPEN FILE 12 FOR PLOTDSN.PATRANG.DATA FILE IS OLD **

** ENTER DSN FOR PLOTDSN.MKIII.DATA. DSN TAKEN FROM HABP RUN

→→→ T\$HABP05 [Geometry data]

IF FILE STATUS OF ** (OLD) ** IS CORRECT, HIT RETURN - IF NOT ENTER NO

→→→ <CR>

```

** OPEN FILE 5 FOR PLOTDSN.MKIII.DATA          FILE IS      OLD **
** ENTER DSN FOR MBYU GEOM NULLFILE (FORMATTED) OUTPUT

--> MBYU.NULL

IF FILE STATUS OF ** ( NEW ) ** IS CORRECT, HIT RETURN - IF NOT ENTER NO

--> <CR>

** OPEN FILE 7 FOR DSN FOR MBYU GEOM NULLFILE(FORMATTED) OUTPUT  NEW **
** OPEN FILE 8 FOR NULLFILE SCRATCH DATA SET-INCLUDES DEFLECTED  SCR **
** ENTER DSN FOR MBYU-T,P,Q..RESULTS(FORMATTED)-[GROWTH ITEM, NOT USED]

--> MBYU.RES

IF FILE STATUS OF ** ( NEW ) ** IS CORRECT, HIT RETURN - IF NOT ENTER NO

--> <CR>
** OPEN FILE 10 FOR DSN FOR MBYU-T,P,Q..RESULTS, NOT USED.          NEW **
** ENTER DSN FOR MBYU GEOM (X,Y,Z COORDINATES OF MKIII)
** OPEN UNIT 11 FOR MBYU GEOM (X,Y,Z COORDINATES OF MKIII)          SCR **

ENTER :  1 FOR NO REFLECTION
         0 FOR   REFLECTION

--> 1

```

PART/POLYGON SUMMARY

COMPONENT NAME	PART NUMBER	BEGINNING POLYGON	ENDING POLYGON	POLYGON TOTALS
NOSE CONE	1	1	36	36
FOREBODY	2	37	76	40
COCKPIT	3	77	156	80
AFT COCKPIT	4	157	172	16
AFT COCKPIT	5	173	220	48
CARGO BAY	6	221	252	32
CARGO BAY	7	253	348	96
AFT FUSE+OMS 1+2	8	349	380	32
AFT FUSE+OMS 1+2	9	381	492	112
AFT FUSE+OMS 3+4	10	493	534	42
FUSE + OMS BASE	11	535	552	18
BODY FLAP STUB	12	553	562	10
BODY FLAP	13	563	602	40
BODY FLAP	14	603	612	10
WING W/ELEVON	15	613	647	35
WING W/ELEVON	16	648	707	60
SURFACE FLAP	17	708	727	20
WING W/ELEVON	18	728	792	65
SURFACE FLAP	19	793	812	20
WING W/ELEVON	20	813	817	5
WING W/AILERON	21	818	845	28
WING W/AILERON	22	846	889	44
SURFACE FLAP	23	890	909	20
WING W/AILERON	24	910	957	48
SURFACE FLAP	25	958	977	20
WING W/AILERON	26	978	981	4
VERTICAL TAIL	27	982	993	12
VERTICAL TAIL	28	994	1023	30
VERTICAL TAIL	29	1024	1053	30
VERTICAL TAIL	30	1054	1069	16
VERTICAL TAIL	31	1070	1089	20
SURFACE FLAP	32	1090	1105	16
VERTICAL TAIL	33	1106	1125	20
SURFACE FLAP	34	1126	1141	16
VERTICAL TAIL	35	1142	1145	4
VERTICAL TAIL	36	1146	1155	10
VERTICAL TAIL	37	1156	1165	10

***** STOP

FOR PRIME COMPUTERS ONLY

1. CONFIGURING THE TERMINAL: (While in the LOCAL mode)

A. Selecting Hard Copier Type

Esc Q D 0 [Invokes black & white copies only - faster]

Esc Q D 1 [Invokes color - slow, requires 4.5min/copy]

B. Color Hardcopy Dithering

Esc Q F 0 [Off]

Esc Q F 1 [On]

C. Color Hardcopy Form

Esc Q F 0 [960 Dots Wide]

Esc Q F 1 [1024 Dots Wide]

D. Color Hardcopy Resolution

Esc Q B 1 [1 Byte Resolution]

Esc Q B 2 [2 Byte Resolution]

E. Color Hardcopy Image Density

Esc Q U 1 [128 Dots/Inch]

Esc Q U 2 [156 Dots/Inch]

2. EDIT GEOM DATA SET:

A. Remove all card images between .NULL and first card image which has all integers at top of data set.

Remove all card images below last card image which has all integers on it at bottom of data set.

Example:

```
ED MBYU.SHUT
TOP
P5
P-3
D3
BOTTOM
P-3
D3
SAVE
QUIT
```

3. USING MBYU:

A. Enter Load Module

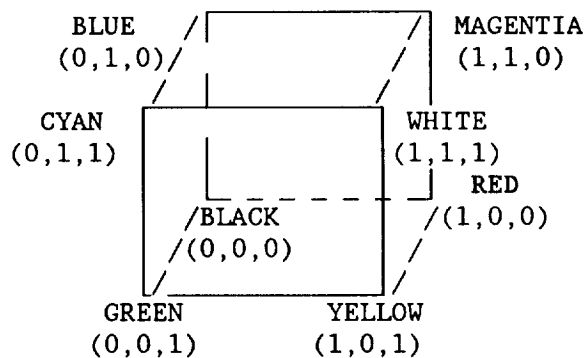
```
--> SEG YDD5310>BYU>DISPLAY.SEG    [MBYU Load Module]
    <MOVIE SYSTEM DISPLAY>
    <READ GEOM FILE>
--> MBYU.SHUT
    <READ DISP FILE>
--> <CR>
    <READ FUNC FILE>    [Future upgrade item, to use results file]
--> <CR>
    >>
```

B. Declare Values for SCOPE

```
--> SCOPE
    <DEVICE>
--> TK15
    <LINE DRAWING OR CONTINUOUS TONE>
--> CT    [Continuous Tone]
    <BLACK/WHITE OR COLOR>
--> CO    [Color]
    <ENABLE DITHERING>
--> N    [No]
    <COMPUTATION RESOLUTION>    [128, 256, 512 or 1024]
--> 128    [1024 gives maximum fidelity but requires long wait time]
    <SAVE SEGMENTS>
--> N    [No]
```

C. Declare Values For COLOR

```
--> COLOR
    <BACKGROUND RED, BLUE, GREEN>
--> 0 0 0    [Black Background on screen]
```



```
    <PARTS I1/I2, RED, BLUE, GREEN>    [Set color for each part]
-->> 1 70 .9 .9 .9    [Set all parts to off-white color]
-->>>    [Prompt allows additional part/color specifications]
-->> <CR>
    <STANDARD FRINGE COLORS?>
-->> Y
    <SYMMETRIC?>
```

```
+++ Y  
  >>
```

D. SMOOTH [Blend shading between parts]

```
  <PARTS I1/I2 NOT SMOOTHED>  
  >>>  
+++ <CR>
```

E. PARTS [Select parts to be used in display]

```
<PARTS I1/I2 WITHHELD FROM DISPLAY>
>>>
<CR>
>>>
→→→ <CR>
>>
```

F. LIGHT

```
<ENTER LIGHT SOURCE NUMBER (1-4)>
→→→ 1
<INTENSITY>
→→→ 1
<PARTS I1/I2, REGULAR LIGHT EXPONENT>
→→→ 1 70 .8
>>>
→→→ <CR>
<HIGHLIGHTS PARTS I1/I2, INTENSITY EXPONENT>
→→→ 1 70 .6 .8
>>>
→→→ <CR>
>>
```

G. DISP [To Set Viewing Angles]

```
→→→ DISP
      ROLL, PITCH, YAW
→→→ -20,-5,135
      <COLOR PASS>
>>
```

H. VIEW [To Plot Color View]

```
→→→ VIEW
```

REFERENCES

1. Woodward, F., "Analysis and Design of Wing-Body Combinations at Subsonic and Supersonic Speeds," AIAA J. Aircraft, Nov-Dec 1968.
2. Gentry, A. E., "Hypersonic Arbitrary-Body Aerodynamic Computer Program Mark III Version," Douglas Report DAC 61552, Vol. I and II, April 1968.
3. Bonner, E., Clever, W., and Dunn, K., "Aerodynamic Preliminary Analysis System, Part I Theory", NASA CR 165627, April 1981.
4. Divan, P., "Aerodynamic Preliminary Analysis System, Part II User's Manual," NASA CR 165628, April 1981.
5. PDA Engineering, "Patran-G User's Guide (Version 1.5)," 1560 Brookhollow Dr., Santa Ana, CA 92705, 1984.
6. Brigham Young University, "Movie.BYU (Version 5.1)," Provo, Utah, 1984.
7. Dunn, K., Proprietary, Undocumented Rockwell International Developed Software, 1985.
8. General Electric CAE Interactive Inc., "GEOMOD Reference Manual."
9. Axtell, W., et al, "Integrated Design and Analysis System User's Manual (Version 4.2, Five Volumes)," May 1986.
10. Williams, J., Butler, S.F.J., and Wood, M.N., "The Aerodynamics of Jet Flaps," ARC R&M 3304, 1963.
11. Sutton, K., "Relations for the Thermodynamic and Transport Properties in the Testing Environment of the Langley Hypersonic CF_4 Tunnel," NASA TM 83220, Oct 1981

APAS II Software Problem Report

327



Report Documentation Page

1. Report No. NASA CR-182077		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Aerodynamic Preliminary Analysis System II Part II - User's Manual		5. Report Date April 1991			
		6. Performing Organization Code			
7. Author(s) G. Sova and P Divan		8. Performing Organization Report No.			
		10. Work Unit No. NA-91-1291			
9. Performing Organization Name and Address Rockwell International Corporation North American Aircraft Los Angeles, California 90009		11. Contract or Grant No. NAS1-18015			
		13. Type of Report and Period Covered			
12. Sponsoring Agency Name and Address National Aeronautical and Space Administration Langley Research Center Hampton, Virginia 23665		14. Sponsoring Agency Code Contractor Report			
		15. Supplementary Notes Langley Technical Monitor: Chris I. Cruz Part II Final Report			
16. Abstract <p>An aerodynamic analysis system based on linear potential theory at subsonic / supersonic speed and newtonian impact type finite element solutions at hypersonic conditions is described. Three dimensional configurations having multiple non-planar surfaces of arbitrary planform and bodies of non-circular contour may be analyzed. Static, rotary and control longitudinal and lateral directional characteristics may be generated.</p> <p>The analysis has been implemented on a time sharing system in conjunction with an input tablet digitizer and an interactive graphics input/output display and editing terminal to maximize its responsiveness to the preliminary analysis problem. CDC 175 computational time of 45 CPU seconds/ Mach number at subsonic - supersonic speeds and 1 cpu second/ Mach number / altitude at hypersonic conditions for a typical simulation indicates that the program provides an efficient analysis tool for systematically performing various aerodynamic configuration tradeoff and evaluation studies.</p>					
17. Key Words (Suggested by Author(s)) aerodynamic analysis subsonic supersonic hypersonic			18. Distribution Statement Unclassified - Unlimited		
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of pages 328	
				22. Price	